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VOL. 7 NO. 6 NOVEMBER, 1920

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JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER AND NOVEMBER

BY THE

AMERICAN WATER WORKS ASSOCIATION

AT MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.

SECRETARY'S OFFICE, 156 WEST 71ST ST., NEW YORK

EDITOR'S OFFICE, 100 LORRAINE AVENUE, UPPER MONTCLAIR, N. J.

Subscription price, $5.00 per annum

Entered as second class matter April 19, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917; authorized August 6, 1918

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VOL. 7 NOVEMBER, 1920 No. 6

SOME ECONOMIC FEATURES OF PUMPING STATION OPERATION[1]

By Leonard A. Day[2]

The object of this paper is to present the results of some of the experiences of the engineering department of the St. Louis Water Division with practical improvements which have resulted in bringing about, within the last five years, a greater economy in the operation of the pumping station.

Inasmuch as the economy of such stations from a heat-saving standpoint deals directly with coal, and owing to the rapid increase in cost of coal throughout the country, it became imperative on the part of the mechanical engineers of the Department to make a thorough investigation of the heat losses existing in their respective plants with a view toward reducing such losses to the lowest possible minimum. When it is considered that the coal cost constitutes probably 40 per cent of the total pumping cost and that in the average pumping plants throughout the country not more than 10 per cent of the heat value in coal is utilized, it is easy to see that the more economical use of coal is highly profitable.

[1] Read before the Montreal Convention, June 22, 1920. Discussion is requested and should be sent to the Editor.

[2] Engineer-in-Charge, Operating Section, Water Division, Department of Public Utilities, St. Louis, Mo.

In passing it would be well to mention the St. Louis experience in storing coal. It was found that practically all grades of bituminous coal can be stored for an indefinite period without any material loss in its heat value, if proper precautions are taken in storing it. The Water Division of the city is provided with storage capacity of 15,400 tons which will maintain a supply sufficient to last over a period of 60 days. Notwithstanding the fact that the city is in close proximity to the Illinois coal fields, the wisdom on the part of the Department of Public Utilities in maintaining this liberal supply for emergency use has manifested itself on several occasions since the beginning of the War. The coal stored is known as 6 inch screened lump and it is piled 16 to 18 feet high in sheds, figures 1 to 4.

Heat value determinations have been made on this coal after having been in storage for a period of 10 years, the results of which show no appreciable heat loss due to storing. Naturally coal loses some of its moisture, and this loss tends to compensate for the heat loss due to some of the volatile gases being set free. The Water Division does not attempt to store Illinois screenings for any length of time. It has, however, stored such screenings, containing about 45 per cent by weight of duff, for one year. By duff is meant coal that will pass through a screen having circular perforations $\frac{1}{4}$ inch in diameter. This coal showed no signs of heating and was placed in a pile about 6 feet high in the open air with no protection from rain or snow. In general, it has been the experience at St. Louis that all bituminous coal free from fines or duff can be stored for an indefinite period without appreciable heat loss, it being preferable to store sized lump coal, placing it so as to minimize breakage.

According to the St. Louis Water Division's experience, the chain grate type of stoker is best suited for burning the low-grade clinkering coal, such as is found in the Illinois coal fields within a radius of 25 miles from St. Louis. This type of stoker is capable of meeting any peak load up to 100 per cent above normal boiler rating, it is simple in construction, easy to repair, it can be operated under all load conditions with natural draft, thereby greatly simplifying the boiler room equipment, and can be operated efficiently on light loads and overloads. Its first cost is about half that of the forced draft underfeed type. A ratio of 1 square foot of grate surface to 48 square feet of boiler heating surface has given the best results, considering the loads and coals. The coal is 2 inch Southern Illinois screenings, having an average heat value of 10,300 B. t. u. with from 20 to 25 per cent ash.

FIG. 1. EMERGENCY COAL STORAGE SHED, CHAIN OF ROCKS STATION

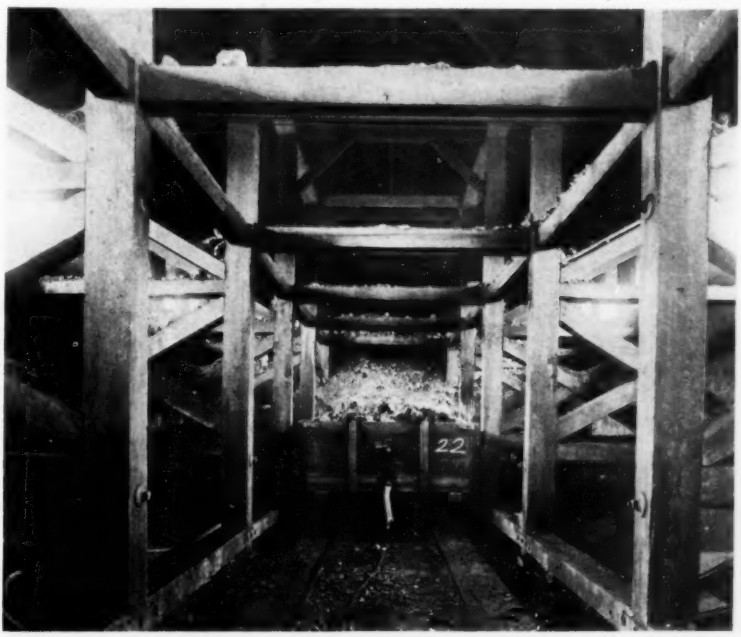


FIG. 2. INTERIOR OF COAL STORAGE SHED, CHAIN OF ROCKS STATION

FIG. 3. EMERGENCY COAL STORAGE SHED, BADEN STATION

FIG. 4. EMERGENCY COAL STORAGE SHED, BISSELL'S POINT STATION

In addition to the proper size grate, experience at St. Louis shows that a properly designed furnace arch and a combustion chamber with sufficient volume to allow complete combustion will add greatly to the efficiency and capacity of the boilers. The first chain grate stokers used by the Water Division were installed at the Chain of Rocks plant in 1914. The stokers were placed under six National water-tube boilers, each of 360 horsepower, and two O'Brien water-tube boilers, each of 250 horsepower capacity. The boilers were set 7 feet from the floor, and the arches were set 11 inches from the grate at the front, and 22 inches from the grate at the rear, the arch being 6 feet 5 inches long. The original arch was set according to the design of the stoker contractor. The boilers were arranged with horizontal baffles, the lower baffle being placed on the second row of tubes. The average boiler efficiency under operating conditions with this setting was approximately 58 per cent and it was difficult to obtain an overload of 25 per cent.

Investigations were started at this station with a view to increasing the boiler efficiency and capacity. It was found that a stoker arch, to function properly, should be set high enough over the grate to allow the volatile gases to be distilled off without being crowded under the arch; also that the shape of the arch should be such as to allow the heat from the bridge wall to be focused on the coal as it enters the furnace. This latter condition is necessary to start combustion in as short a time after the coal leaves the feed gate as possible, so that every available foot of grate surface is utilized for burning coal. By referring to figure 5, which shows the original arch, it will be apparent that from the standpoint of obtaining a large liberating volume under the arch and an efficient shape of the roof, so as to obtain the maximum benefits of heat reflection coming from the bridge wall, this arch did not function properly. Referring to the lines bearing arrows indicating heat rays, it will be observed that this arch does not permit a concentration of heat at a point where a maximum concentration is desired, namely, at the point of ignition. These objectionable features have been overcome by the new design of arch shown in figure 6.

In this setting, the distance from the floor to the front water leg remains 7 feet, being determined by the original setting of the boiler. The arches are set 12 inches from the grate at the front end, rise rapidly to a hip, and are 36 inches high at the rear. The length of the arch is $6\frac{1}{2}$ feet. This arch has a better concentration of heat

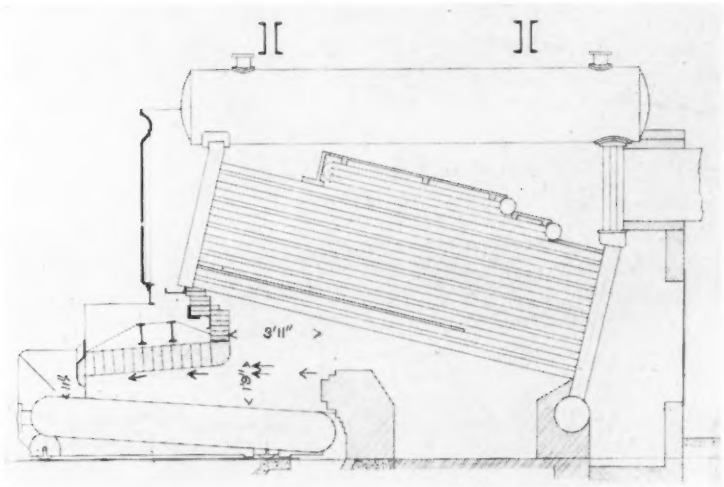


FIG. 5. ORIGINAL BOILER SETTING, CHAIN OF ROCKS

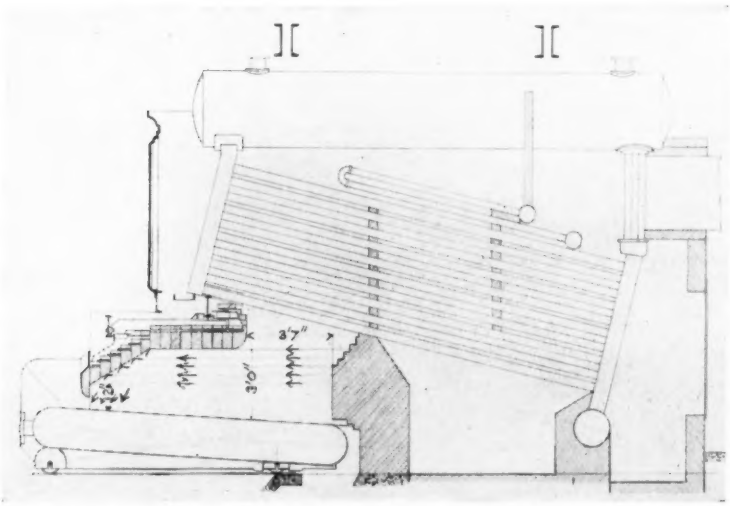


FIG. 6. IMPROVED BOILER SETTING, CHAIN OF ROCKS

rays near the feed gate, the rays being reflected from the bridge wall, than the one shown in figure 5, due to obtaining an arch contour which approximates the curve of a parabola, in which curve all reflected heat rays concentrate at the focus. To illustrate, figure 7 shows a parabolic curve superimposed on the improved arch.

Comparative tests made before and after the change in the arch shape resulted in the following:

With the old type arch, on a capacity test run by the stoker contractor, an evaporation of 15,770 pounds of steam per hour was maintained for ten hours. With the new style arch an evaporation of 17,140 pounds of steam per hour was maintained for five hours. The former represents an overload of 38 per cent while the latter represents an overload of 60 per cent. At the same time the average boiler efficiency was increased from 58 per cent to 63 per cent, or a gain in efficiency of approximately 9 per cent. After all boilers have been equipped with the new arch, it is estimated that the saving in annual coal cost will amount to about $5000 at this station.

A similar improvement in capacity and efficiency was made at the Bissell's Point Station. The boilers at this station are set with the front water leg 6½ feet above the floor line. The original arches were sprung transversely across the grate 9 inches above the grate at the hip, rising to 18 inches above the grate at the center. Longitudinally the arch was parallel to the grate. This type of arch, that is, in respect to the low height above the grate, was the common practice among chain grate stoker builders up to within but a few years past. The arch was removed and replaced with a new type of flat arch, which is 12 to 13 inches above the grate at the feed gate and rises straight, without a hip, to 30 inches above the grate at the rear end. The length is 7 feet. It was not possible to construct a hipped arch at this station because of the limitation of the low setting. However, a good saving was effected for the reason that prior to the change in arch design, it was only possible to burn crushed egg or lump coal at this station, due to the low arches, which did not effect a proper ignition with the lower grades of screenings. The new arch makes it possible to burn the lower grades of screenings successfully, and obtain the same evaporation per pound of coal with screenings as with the crushed egg or lump coals, thereby resulting in a saving in the price of coal of about 18 per cent. This 18 per cent saving in the price of coal, when applied to last year's coal cost at this station, amounts to an annual saving in coal cost of about $10,000. Also,

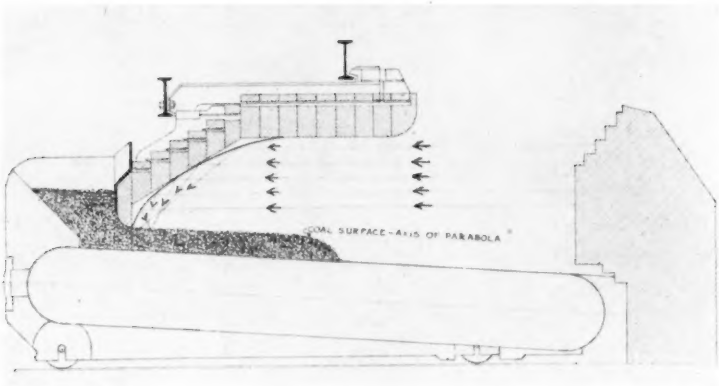


FIG. 7. APPROXIMATION OF NEW ARCH TO PARABOLIC CURVE

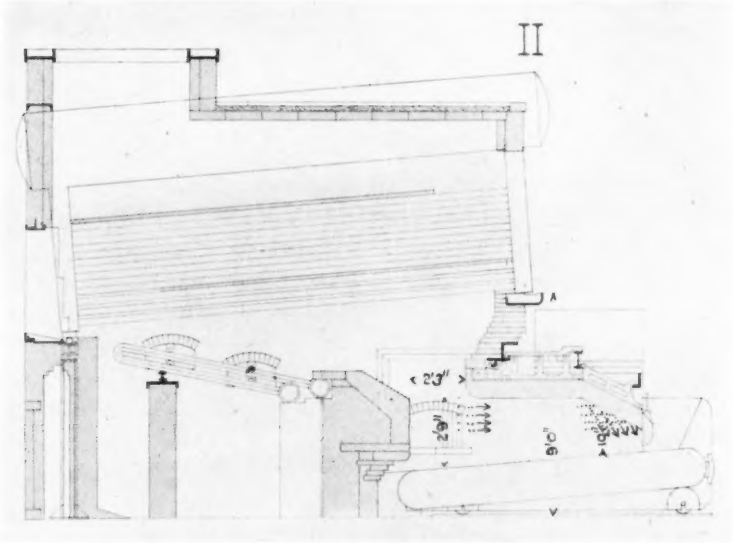


FIG. 8. NEW BOILER SETTING, BADEN STATION

after all the boilers at this station were equipped with the new type arch, the average overall rating of the boiler room rose from 90 to 115 per cent, even with the use of a lower grade of coal.

Although it was realized after the new arch was designed, that the setting was not perfect, the boilers being too low, yet even with the low setting the arch has given the improvement in capacity and efficiency mentioned above, permitting one boiler to be taken off the line.

The results of experiences with the two installations, led to the adoption in the installation of new boilers at the Baden plant, of a setting which is believed to eliminate all objectionable features found by previous experience. Figure 8 shows a cross section through this setting. The arch is similar to that of the new arch for the Chain of Rocks Station; the distance at the feed gate above the grate is 10 inches, rising rapidly to a hip, and is 34 inches above the grate at the rear. The length of the arch is 7 feet. The height of the front water leg above the floor is 9 feet, this height providing a larger combustion chamber than in the previous settings, thereby obtaining a more thorough mixing of the gases and oxygen, and providing a relatively longer gas travel, all of which are necessary for the efficient burning of coal at high rates of combustion. The evaporation at this station averages $6\frac{1}{2}$ pounds of water per pound of coal at a boiler efficiency of 66 per cent. Comparing this performance with that of the other stations, when the old type of settings prevailed, shows a saving of about 13.8 per cent in coal.

As has been previously stated, the over-all boiler efficiency of the other two stations is 63 per cent with the improved arch, while that at the Baden station, with practically the same style arch as was adopted at the other stations, shows an over-all boiler efficiency of 66 per cent. This increase of 3 per cent in efficiency, or a gain of 4.8 per cent, may be attributed to the higher boiler setting, namely 9 feet instead of 7 feet, which prevails at the other two stations. In other words, by setting the boilers 2 feet higher at the Baden station, a gain of 4.8 per cent in over-all boiler efficiency has been made. This gain, when computed on the annual cost of coal at this station, amounts to $3,000 annually.

An operating over-all boiler efficiency of 66 per cent, using Southern Illinois screenings of 10,300 B. t. u. per pound and meeting a variable daily load, may be considered as good as can be expected from this type of boiler room installation.

The actual cost of rebuilding the arches at the Chain of Rocks and Bissell's Point Stations amounted to about $300 per arch or a total of $4200, while the saving in coal effected due to these changes amounts to approximately $15,000 per year. The entire work of rebuilding the arches was paid for in 3½ months.

The above mentioned gains are principally due to the improvement in furnace design, but part of the saving in coal must be credited to improvements made in our boiler baffling.

Boiler baffling should be so placed as to force the gases into contact with all parts of the tube bank. In the older Heine type of settings of the stations, the lower baffle was made of box tile on the lower row of tubes and the upper baffle was 13 tubes above on the top row of tubes. The opening in the lower baffle was in some cases as much as 60 inches from the rear water leg. The path of the gases in this type of boiler was diagonally upward through the tubes leaving the rear water leg and the tube ends near it untouched by the hottest gases, and leaving a dead triangular pocket at the bottom of the front water leg.

By eliminating the box tile on the lower row of tubes and placing a specially designed tile on the third row of tubes, and also reducing the opening in the lower baffle from 60 to 42 inches, the flue temperature was reduced from an average of 650°F. to an average of 550°F.

It will be apparent from figure 8 that the velocity of the gases is higher through the tubes, thereby reducing the insulating effect of the film of idle gas around the tubes and resulting in a better heat absorption. It will also be apparent that the bottom rows of tubes are now exposed to the radiant heat of the flames; thus by raising the baffle tile onto the third row of tubes, the gases are crowded into more intimate contact with the tubes, dead pockets in the passes are destroyed, and the lower row of tubes, by absorbing the radiant heat of the flames, tends to lower the temperature of the surrounding walls of the combustion chamber, which in turn tends to increase the life of the setting.

When it is remembered that roughly there is a gain of 1 per cent in boiler efficiency for every 25°F. reduction in flue temperature, it will be seen that there was an approximate gain of 4 per cent in efficiency for the 100°F. drop just mentioned, a gain effected by merely placing the boiler baffling in a better location and at a negligibly small cost.

Simultaneously with the installation of chain grate stokers, superheaters were installed in the boiler settings, as shown in figure 9.

For determining the size of superheaters, accurate gas temperatures were taken at the place where the superheaters were to be located, and steam, load, and firing conditions noted simultaneously as an aid to the manufacturer of the superheater in arriving at its proper size.

In the case of horizontally baffled boilers, the superheaters are located in the combustion chambers back of the bridge wall, and in the vertically baffled boilers, the superheaters are located under the shell between the first and second pass. Although the location behind the bridge wall is apparently a severe location, yet it has been the experience at St. Louis that if the superheaters are not within the direct path of the flame, they show no effects of the heat and promise a long life. The advantages of the location in the combustion chambers are a smaller superheater and greater accessibility.

The use of superheated steam at all of the plants has proved to be one of the greatest factors in increasing the efficiency of the engine rooms.

Superheated steam in the cylinder of a steam engine transfers heat to the cylinder walls, but instead of condensation occurring on contact, as with saturated steam, the superheat must first be withdrawn. Superheated steam maintains a higher cylinder wall temperature and if superheating is carried far enough, condensation can be delayed until after cut-off and even until expansion is partly completed. Also the specific volume of superheated steam is greater than that of saturated steam and this increase in specific volume, the pressure being constant, diminishes the weight of steam to the engine, and has an influence on the economy gain, as has also the lower thermal conductivity of superheated in comparison with saturated steam.

The Water Division has made tests on the effects of superheated steam on triple expansion and on compound pumping engines.

The triple expansion engines, which pump against a head of 85 to 125 pounds pressure and have capacities of 15,000,000 to 20,000,000 gallons daily, showed the saving for various degrees of superheat given in figure 10. The steam saving for 100° superheat amounted to 12.1 per cent, while the saving in coal amounted to 7.5 per cent.

The low-service compound pumping engines, which pump against a maximum head of 65 feet or about 28 pounds pressure, and have a nominal capacity of 30,000,000 gallons daily, showed the saving for various degrees of superheat given in figure 10. The steam sav-

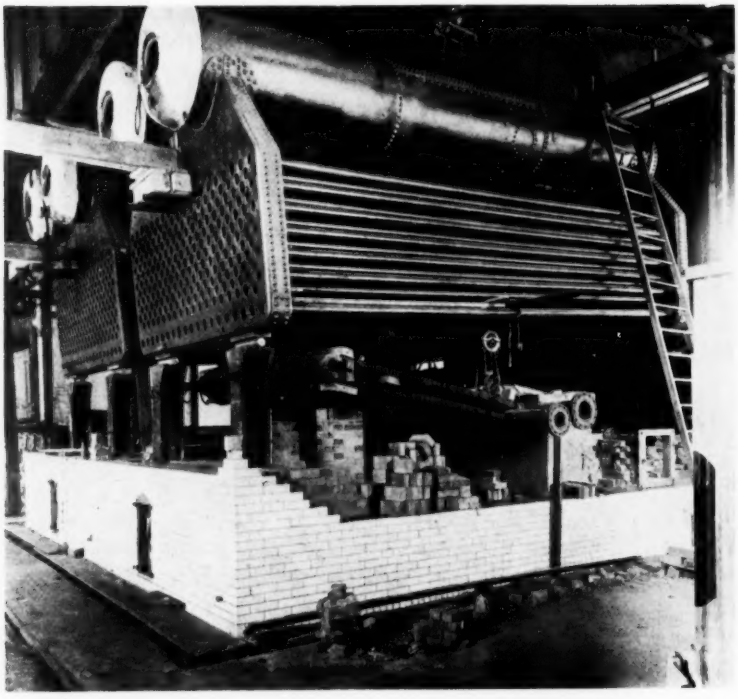


FIG. 9. NEW BOILER SETTING, BADEN STATION

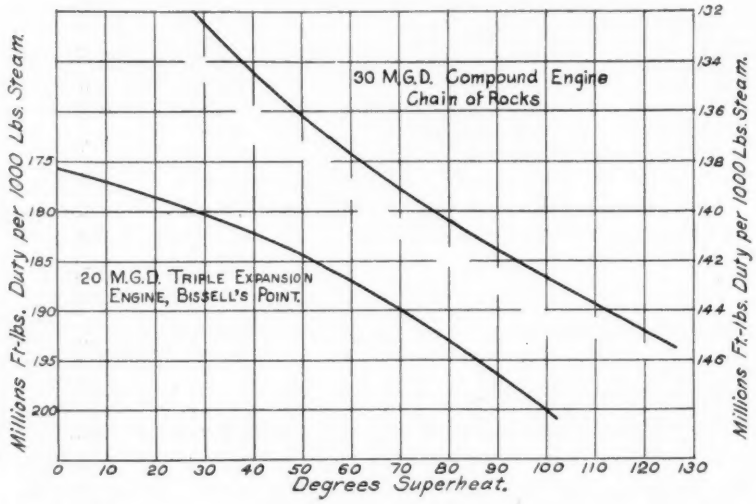


FIG. 10. EFFECT OF SUPERHEAT ON COMPOUND AND TRIPLE EXPANSION PUMPING ENGINES

ing for 100° superheat amounted to 17.3 per cent while the saving in coal amounted to 13.2 per cent.

The saving in coal due to the introduction of superheated steam into the Chain of Rocks stations has been sufficient to pay for the superheaters in about $3\frac{1}{2}$ years. The life of a superheater, when the elements are not exposed to the direct flame, should be equal to the life of the boilers.

It is commonly accepted that the degree of superheat for the usual equipment of engines and pumps is limited by a total temperature of 500°F., especially when using cast-iron fittings. The Water Division has resorted to the use of cast steel fittings and valves on all new pipe work. The new piping was not installed solely with the idea in view of meeting the total temperatures of the superheated steam which it was intended to use, but also to insure more reliable service in all of the pipe lines than cast iron fittings and valves would give. However, in one of the plants the original extra heavy cast iron fittings made by a reputable manufacturer have given excellent service with a total temperature of as high as 500°F. These fittings have been in service some five years under superheated steam conditions without showing any apparent signs of weakness.

While speaking of steam piping, the following quotations in favor of superheat are given:

> Due to the absence of moisture, superheated steam offers less friction passing through pipes than saturated steam, therefore, the speed of travel can be higher and the piping, fittings and valves smaller. When piping is designed especially for superheated steam, the reduction in size will go far towards paying for the superheaters. Where it (superheated steam) is turned into an existing system of piping, the radiation may be somewhat greater than if the piping were of proper size, but the reduction in pressure would be less. The actual radiation from superheated steam, under similar conditions, is less than it is with saturated steam, because, even though the temperature is higher, its low conductivity makes it lose heat less rapidly. Besides, the pipes are not so wet and hence have less conductivity. Depending on the steam speed and the pipe protection, superheated steam is figured to lose 1° of superheat in from 6 to 10 feet of travel.

Reverting again to the tests made on the compound pumping engine to determine the effect of superheat. The pumping engine, when it was originally installed 25 years ago, developed a duty of 118,000,000 foot-pounds per 1000 pounds of saturated steam, no superheat being used at this time. The pumping engines at this station were all bought on the bonus and forfeiture basis, which naturally led the contractor to make every effort toward obtaining

the very highest duty possible. The Water Division, however, in running the duty tests with variable degrees of superheat, made no attempt whatever to increase the economy of the pumping unit before the test was run, by increasing the vacuum, repacking the plungers, renewing pump valves, inspecting valves and pistons, and so forth. In other words, the test was run on a pump operating under every day plant conditions and even with a superheat of only 28°, which is the lowest obtainable, the pump developed a duty of 132,000,000 foot-pounds per 1000 pounds of steam, which is a saving of 11.9 per cent in steam consumption over that of the original duty test with saturated steam. This is a very creditable showing for a pump that has been in service for 25 years.

As previously mentioned a better saving by the use of superheated steam was expected in compound low-service pumping engines than in the high-service triple expansion engines, for the reason that a compound pumping engine of the usual cylinder proportions is not as economical as a triple expansion pumping engine, due to a greater heat drop in each cylinder causing a greater cylinder condensation. As superheated steam specifically functions to prevent cylinder condensation, it follows that its greatest virtue will be manifested in the less economical engine.

There seems to be, to the author's knowledge, a prevailing impression in a great many water works plants, that the use of superheated steam with its consequent economies is offset by difficulties with lubrication. This contention is not borne out by the experience of this Division.

In lubricating engines using superheated steam, the only parts which actually come into continuous contact with superheated steam are the inlet valves on the high-pressure cylinder, for all other parts of the engine beyond this point, cylinder and piston, are at a mean temperature lower than the steam temperature entering, due to the fact that steam with even 100° superheat becomes saturated by the time the piston travels to the point of cut-off in the high pressure cylinder. The lubricating problems were found to be no more difficult with superheated steam than with saturated steam. The cylinder oil possesses the following characteristics, to quote from the specifications:

> Cylinder oil shall be a compounded oil of 2 per cent pure acidless oil, and 98 per cent pure filtered mineral oil. It must be free from dirt, grit, lumps and specks; transparent amber in thin film; bright ruby through neck of four-ounce bottle; translucent greenish by reflected light. It must satisfactorily pass the following tests:

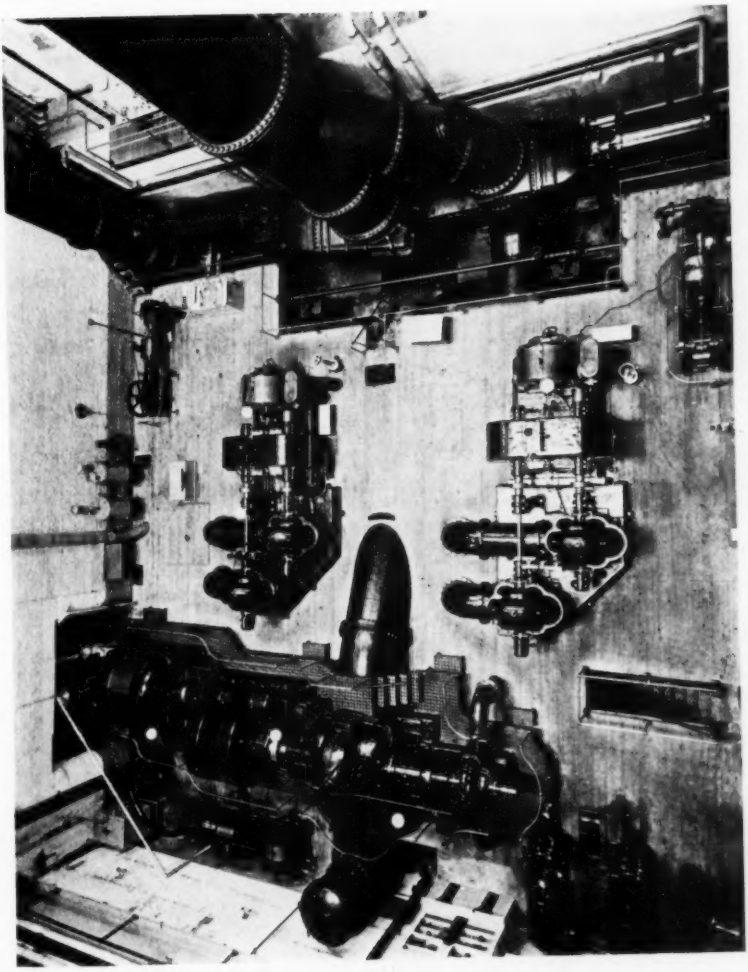


FIG. 11. MIDDLE PIT, CHAIN OF ROCKS STATION, WITH NEW 100,000,000-GALLON STEAM-TURBINE-DRIVEN CENTRIFUGAL PUMP AND TWO 35,000,000-GALLON SIMILAR UNITS

Specific gravity.—26° to 28° Baumé at 60° Fahr.
Flash point.—Must not flash below 540° Fahr.
Burning point.—Must not burn below 600° Fahr.
Viscosity.—Must not be less than 3.75 (Engler) at 212° Fahr.
Cold test.—Must flow readily at 50° Fahr.
Water.—Must not froth or bump when heated in flash cup.
Tarry and suspended matter.—5 ccm. of this oil shaken with 95 ccm. of 88° petroleum ether in a glass stoppered graduate must show no precipitation of tarry and suspended matter.
Volatility.—Heated for two hours at a temperature of 400° Fahr. this oil must not show a loss of more than 5 per cent by weight.
Saponification.—When oil is treated with alcoholic potash it must show a presence of 2 per cent tallow oil.

For a short period, a straight mineral oil with no tallow was used as cylinder oil with superheated steam, but was soon found to be unsatisfactory. It was found that the compounding with tallow was necessary.

The steam-turbine driven pumps are installed in the same station with the low-service compound pumping engines previously referred to. Two of these are of the single-stage centrifugal type, each of a nominal capacity of 35,000,000 gallons of water a day. They were installed in 1913 and have been in active service ever since. The test duty of these pumps, at a head of 65 feet was 100,000,000 foot-pounds per 1000 pounds of saturated steam.

A recent test run under the same pumping conditions, but with 124° of superheat instead of saturated steam, showed a duty of 115,-000,000 foot-pounds per 1000 pounds of steam, an increase in duty of 15 per cent. The physical condition of the pump may be said to have been the same during both trials for the reason that the unit had just been overhauled, a new steam wheel installed, nozzles rebored and new pump impeller wearing rings installed, when the test with superheated steam was made.

On the same turbine-driven centrifugal pump, comparative tests were made to determine the difference in duty, with the same superheat of 82° and the same vacuum, before and after the pump was overhauled as just described. The duty before overhauling was 93,500,000 foot-pounds per 1000 pounds of steam. The duty after overhauling was 106,000,000 foot-pounds per 1000 pounds of steam, showing a saving of 13.3 per cent, due entirely to overhauling.

It might be well to mention that the pumps at the low service station are subject to abnormal wear due to their pumping raw river water containing a great deal of sand in suspension.

THE PROBABILITY CURVE[1]

By William L. Hart[2]

In many parts of the general theory of statistics and in innumerable particular problems of a statistical nature, fundamental use is made of the normal probability curve. There is great danger in using any tool if its exact field of applicability is unknown and if its internal mechanism is not understood. A danger of this type is in view whenever a statistical worker uses the probability curve. For, of all the tools furnished by pure mathematics to the person applying mathematical methods, the probability curve, or law of errors, is one of the least perfect from a logical point of view. It is not the purpose of this paper to present a cure for these logical deficiencies or to give a mathematical discussion of the derivation of the probability curve. The reader who is interested in results of this character should consult the references listed in the footnotes of this paper.

In Section 1 of the present discussion, an example will be given showing how the normal probability curve arises naturally in certain statistical problems. Another example of a type apparently similar to the previous one will then be given where, nevertheless, the same procedure as before does not lead to a normal curve. In spite of the fact that the normal curve has a field of applicability the extent of which has not been clearly defined, there are certain conditions, met many times in practical work, under which the normal law of probability holds. In Section 2 one set of such conditions will be given. In Section 3 certain useful properties of the normal curve will be described.

1. Statistical examples and frequency curves. Let us consider the analysis of the results which, under ideal conditions, would be obtained in firing a gun at a target T in a plane. In figure 1 let T represent the target and suppose that the gun is in the direction

[1] Read before the Minnesota Section on May 3, 1920. Discussion is desired and should be sent to the Editor.

[2] Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.

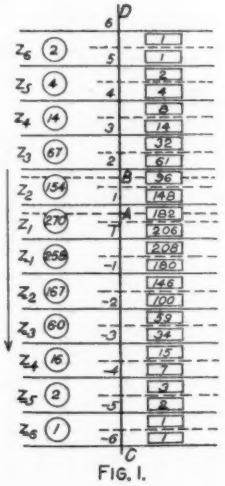


FIG. 1.

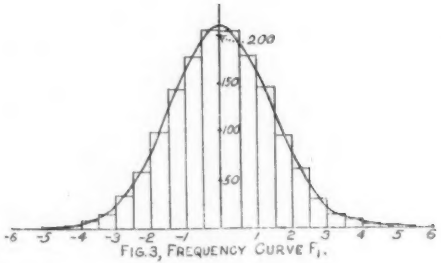


FIG. 3, FREQUENCY CURVE F_1.

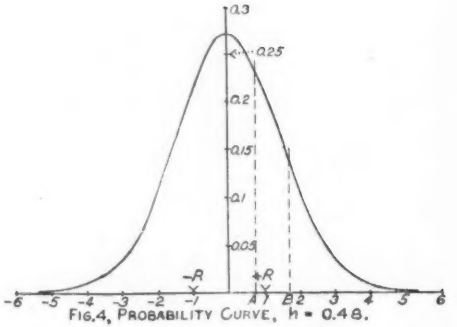


FIG. 4, PROBABILITY CURVE, $h = 0.48$.

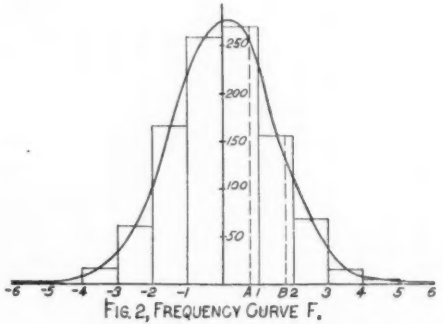


FIG. 2, FREQUENCY CURVE F.

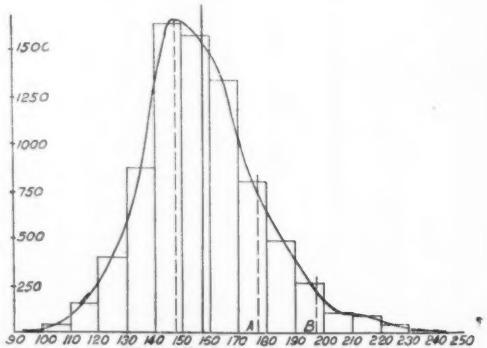


FIG. 5, FREQUENCY CURVE G.

EXAMPLES OF FREQUENCY AND PROBABILITY CURVES

indicated by the arrow. Draw a line CD through T and the gun and lay off a scale on CD as indicated in the figure. The full lines through the division points of the scale divide the plane into zones Z_1, Z_2, etc., and Z_{-1}, Z_{-2}, etc. Suppose, now, that a great many shots are fired at T with a perfect gun, perfectly aimed, on a day when all weather conditions are perfectly normal. Under such conditions, every shot should hit T provided the powder charge used in firing had the proper weight and the projectile fired had been made with absolute accuracy. Let us assume that these last two ideal conditions are not satisfied. Consequently, the shots fired at T will fall in varying numbers in the different zones. Assume that the results of the firing are as shown by the numbers in the circles in figure 1, where each number indicates how many projectiles of the total fell in the corresponding zone.

Consider the construction of a graph of the results as given in figure 2. The horizontal scale is a duplicate of that on CD. The vertical scale has been chosen at will. On each section of the horizontal scale erect a rectangle whose height equals the number of projectiles which fell in the zone corresponding to the section. The resulting figure is called a histogram.[3] In the units used for the scales in figure 2, the total area of the histogram equals the number of shots fired, multiplied by the width of a zone, which in this case is 1. If we were to fire a single additional shot, then, on the basis of our experience as given by figure 2, the probability of the projectile falling in the part of the plane between lines in figure 1 through A and B is approximately equal to *the area of the histogram between vertical lines through A and B in figure* 2 divided by *the total area of the histogram.* Let us call this characteristic property of the histogram the *probability property.*

In figure 2 mark the centers of the tops of the rectangles and through these points draw a smooth curve F which is termed an approximate *frequency curve*[4] for our data. Since the area under any section of the curve F is approximately that under the corresponding part of the histogram, it is clear that F also possesses the probability property which was noted in the case of the histogram.

Assume, now, that we have conducted a new firing program in which many more projectiles were shot than before. Since better classification would be possible because of the added data let us

[3] Introduction to the Theory of Statistics, G. U. Yule, page 84.
[4] Introduction to the Theory of Statistics, G. U. Yule, page 87.

make smaller zones in figure 1 as indicated by the dotted lines. Let the results of the firing be shown by the numbers in rectangles in each of the new zones. For these new data the histogram and frequency curve F_1 are given in figure 3. The total area under F_1 is different from that under F but the probability property holds for F_1 in exactly the same form as it did for F.

Let us draw curve F anew with the vertical distances of each point from the horizontal axis reduced by such a factor that the area under the new form F' of the curve will be 1. Suppose that the same procedure were followed in the case of the curve F_1 giving a new curve F'_1, the area under which would also be 1. In the present problem the curves F′ and F'_1 are so nearly identical that, as a consequence, in figure 4 only one curve is given which may at will be considered as F' or as F'_1. In figure 4, after the reduction of the verticals mentioned above was made, the vertical scale was magnified in order to give a clear figure. Since in passing from figure 2 or figure 3 to figure 4 all parts of the area under F or F_1 were changed proportionately, it follows that, since the area under F' or F′$_1$ is 1, the probability property holds for F' or F'_1 in the following simplified form:

On the basis of the data from which F or F_1 was obtained, the probability of a shot falling between A and B in figure 1 equals the area under the curve F′ or F'_1 in figure 4 between the verticals through A and B.

Let us call F' and F'_1 *approximate probability curves.*

If we made more and more firings, classified the results in zones of smaller and smaller width, drew the corresponding frequency curves and, from them, the approximate probability curves, the latter would approach a definite limiting form. As a result of certain theoretical conclusions to be quoted in Section 2 it can be stated that this limiting form would be a *normal probability* curve; that is, a curve whose equation in coördinates (x, y), as indicated in figure 4, would be given by the equation

$$y = \frac{h}{\sqrt{\pi}} e^{-h^2x^2} \qquad (\pi = 3.1416;\ e = 2.7183) \qquad (1)$$

for some value of the positive constant h. In the present ideal firing problem the value of h is approximately 0.48. A different normal curve would be obtained for every type of gun which might be used in the firing, or, in other words, a different value of h would be determined for which formula (1) would represent the probability curve

for the gun in question. For a given gun, the probability curve would change if the distance of T from the gun were changed.

In actual firings at the Artillery Proving Grounds of our army, when it is necessary to determine the probability curve corresponding to a given gun when fired at a target T at a given distance, the mode of procedure differs from that outlined above. From the firing results as given, for example, in figure 1, an approximate value of h is immediately found by means of a formula to be given in Section 3 and the probability curve is then constructed by means of formula (1) above.

As a second example of a statistical nature consider the following analysis of the weights of men in England, Ireland, Scotland and Wales. This problem[5] is cited by G. U. Yule who obtained the data from the Final Report of the Anthropometric Committee to the British Association (1883), page 256. In the table below, the first column gives the lower ends of the 10-pound weight intervals in which the weights of the men were classified. The second column gives the number of men whose weight fell in the corresponding interval.

WEIGHT	NUMBER OF MEN
pounds	
90	2
100	34
110	152
120	390
130	867
140	1623
150	1559
160	1326
170	787
180	476
190	263
200	107
210	85
220	41
230	16
240	11
250	8
260	1
270	0
280	1

[5] Introduction to the Theory of Statistics, G. U. Yule, page 95.

The mean, or average, weight of the 7749 men examined is found to be 157 pounds.

On treating these data by a method similar to that used in the artillery example, we obtain a histogram and a frequency curve G as given in figure 5. The heavy vertical line in this figure goes through 157 on the horizontal axis, the point corresponding to the mean of the weights measured. Consequently, the area under G to the right of this vertical equals the area to the left. On the basis of the data used in this example, the probability that a man selected at random would have a weight between A and B pounds equals *the area under G, between vertical lines in figure 5 through A and B on the horizontal axis, divided by the total area under G.*

If an approximate probability curve G' should be obtained from G as was done in figure 4 of the previous example, G' would retain the property, possessed by curve G, of being unsymmetrical with respect to the vertical line through 157 on the horizontal scale and unsymmetrical with respect to the vertical line through the highest point of the curve. Hence, the curve G' could not be approximately represented by a normal probability curve because, in such a curve, the area beneath it is divided into two equal parts by the vertical line through the highest point. Nevertheless, if the data for the present example were progressively increased and were then classified more finely, and if the corresponding approximate probability curves were drawn, they would approach a limiting curve which, however, would not be a normal probability curve. In spite of this fact, the limiting curve would possess the probability property and would be very useful in any further discussion of the problem.

To almost every statistical problem of the type considered here there corresponds some sort of a limiting probability curve. In a great majority of cases, the problems are of such a type that it is impossible to state at the beginning, as was done in the artillery problem, that the probability curve will be normal. Hence, the only proper and safe mode of procedure in a statistical investigation is to construct the frequency curve and then to determine by inspection whether or not it could possibly lead to a normal probability curve. If it is found experimentally or by theoretical reasoning that the probability curve for the problem is normal, the properties of the latter may then be used in the further discussion of the example.

2. The normal curve as a curve of errors. If a given quantity is being measured, errors naturally enter in the use of the scales of the measuring instruments. For example, in five measurements of the length of a bar we might obtain the following results: 16.16, 16.18, 16.17, 16.19, and 16.15 inches. The arithmetic mean, or average, of these results is 16.17 inches. The *deviations* of the measurements from the mean are: -0.01, $+0.01$, 0.0, $+0.02$ and -0.02 inch. Suppose that we have made a long series of different measurements of the size of some given magnitude and let us tabulate the deviations of the individual measurements from the mean of all the measurements. Then, as in Section 1, from these tabulated data we could obtain a frequency curve F showing the frequency of occurrence of deviations of various sizes. From F in turn we could obtain an approximate probability curve F'. In regard to this last curve we can state the following theorem:[6]

Theorem. Suppose that a given magnitude is being measured and assume that errors in the individual measurements are wholly due to accidental causes. Then, as the number of measurements becomes infinitely large, the approximate probability curve F', showing the probability of occurrence of deviations of various sizes, approaches a normal probability curve.

The term *accidental* is applied to errors which are due to irregular causes which operate to increase observations as often and in as great a degree as they tend to decrease them, and whose effect upon an observation is independent of the individual character of that observation. The practical significance of the words *infinitely large* is that we should not expect an approximate probability curve for a problem to correspond very closely to a normal curve unless the number of entries in our data was very large.

The theorem above is stated in terms of the word *measurement* but the result remains true for any set of data which possesses the same characteristics as a set of measurements subject only to accidental errors of observation. Therefore it follows from the properties of accidental errors that, if the theorem holds for a set of numerical data, the deviations of the individual entries from the mean of the whole set of data must satisfy the following conditions:

[6] For proof of this theorem see Method of Least Squares, D. P. Bartlett, Chapter 1, or Calcul des Probabilities, H. Poincaré, Chapter X. For logical objections to the proof of the theorem see Poincaré, loc. cit., page 173.

(*a*) Positive deviations are as frequent as negative deviations of the same magnitude.

(*b*) The probability of the occurrence of large deviations is very small and that of small deviations is relatively large. It is easily seen that the frequency curve for such a set of data must necessarily be of the symmetrical type met in the first example of Section 1. The maximum of such a curve comes directly above the point on the horizontal scale corresponding to the mean of the whole set of data.[7]

Consider the artillery example of Section 1 in its relation to the theorem. Deviations of the points of fall of the projectiles from the target T were due wholly to accidental errors in the manufacture of the projectiles and of the powder charges. Hence, deviations of the points of fall, which make up the data considered in Section 1, must have the same nature as the accidental errors of manufacture by which they were caused. Consequently the theorem applies and therefore the probability curve for the problem must be normal.

Consider the second example of Section 1. In this case the frequency curve was found to be unsymmetrical. Hence, conditions (*a*) and (*b*) above cannot hold and therefore the probability curve for the problem is not normal.

It must not be inferred that the conditions of the theorem are the only ones under which it can be established that a normal curve results. The probability curve can be derived from many different points of view[8] and only one has been presented in this section.

3. Properties of the normal curve. The graph in figure 4 shows the form of the normal probability curve for the special value $h = 0.48$. Consider for a moment the five measurements of the length of a bar given in Section 2. The deviations from the mean were -0.01, $+0.01$, 0.0, $+0.02$, and -0.02 inch. If we add these deviations, making all the signs positive, we obtain 0.06 inch. The *average deviation*—in notation, the A. D.—of the observations is defined as $0.06 \div 5 = 0.012$. For a general set of data we similarly define the A. D. of the data as *the sum of all the deviations taken with a positive sign* divided by *the number of entries making up the data.*

[7] A very complete study of such frequency curves is found in Yule's Introduction to the Theory of Statistics, Chapter VI.

[8] See Calcul des Probabilities, Poincaré, Chapter X, and Introduction to the Theory of Statistics, Yule, Chapter XV.

The A. D. of a set of data is very easy to compute[9] and serves as a basis for determining other properties of the data.

Assume that we are dealing with a group of data for which the probability curve is normal (suppose its graph is given by figure 4). Then, it can be easily proved[10] that the value of h in formula (1) which gives the normal curve for the problem is related to the A. D. of the data by the equation

$$h = \frac{1}{\sqrt{\pi}\,(\text{A.D.})}.$$

In the artillery example of Section 1 the A. D. for the group of data in circles in the large zones is found to be 1.194 which gives $h = 0.47+$. For the group of data in rectangles, the average deviation is 1.164 and the corresponding value of h is $0.48+$. In a statistical problem where the probability curve is desired, the most simple procedure usually is to compute the A. D. of the data and from it the value of h, after which the probability curve can be obtained by formula (1). This method replaces the more involved steps illustrated in Section 1.

In regard to figure 4 it was stated that the probability of a shot falling between A and B in figure 1 was equal to the area under the probability curve lying between vertical lines erected at points A and B on the horizontal axis in figure 4. For a general set of data, we may state that the probability of a deviation having a value lying between A and B is equal to the area under the probability curve between the verticals at A and B. The area under the whole curve is 1. Therefore, there are points, $+R$ and $-R$, on the horizontal axis such that the area under the probability curve between the verticals erected at these points is $\frac{1}{2}$. In other words, R is such a number that the chances are even that a deviation will exceed R in numerical value. This value R for a set of data is called the *probable error* of the data, and it can be proved[11] that it is related to the A. D. by the equation $R = 0.8453$ (A. D.). In the artillery example, the two sets of data give respectively, $R = 1.01$, and $R = 0.99$. It can be proved that there is less than one chance in 100 of a deviation being greater than $4R$ in numerical value. Another quantity,

[9] See Introduction to the Theory of Statistics, Yule, Chapter VIII.
[10] Method of Least Squares, Bartlett, Chapter III.
[11] Method of Least Squares, Bartlett, Chapter III.

called the mean error, M, or *standard deviation*, is of importance in its relation to the normal curve. This quantity[12] satisfies the equation

$$M = \frac{1}{h\sqrt{2}} = 1.4826\, R$$

It is beyond the scope of this paper to consider the applications of the probability curve, the mean square deviation and the probable error in statistics and the reader who desires a brief discussion of these should consult a paper[13] by E. V. Huntington on "Mathematics and Statistics."

[12] Introduction to the Theory of Statistics, Yule, Chapter XV, where the subject is discussed in great detail.

[13] American Mathematical Monthly, Vol. 26 (1919), page 421.

STANDARDS OF QUALITY OF WATER[1]

By Jack J. Hinman, Jr.[2]

In thinking of the quality of a water, it is natural to think first of its potability or sanitary quality, then of its physical attractiveness and finally of its suitability for steam making and other industrial uses. In certain cases the suitability for industrial use takes precedence, but when considering a water supply for a community, choice is commonly determined by the potability and attractiveness, assuming that all sources under consideration can yield a sufficient quantity of water to supply the needs of the community in question, and that the cost of supplying water from the different sources is not subject to too great variation.

The consumer is likely to assume that the water is safe to use and to direct his notice to the physical properties. Color, turbidity, taste, odor, temperature, and to some extent the mineralization make their appeal directly to his senses, and he is apt to judge a water supply on the basis of the conditions with which he happens to be familiar. Local habituation to various types of water that may be common in the particular part of the country in question so frequently determines what will be accepted as satisfactory for public use that the author does not intend to discuss these factors in detail, important though they are. He prefers rather to confine himself to a topic, itself sufficiently broad, that of the standards of the sanitary quality of water supplies, which are supposed to aid in reaching conclusions as to the safety of water supplies for drinking purposes.

It is not the author's intention to attempt to duplicate either the masterly paper by Johnson[3] on "Pure and Wholesome Water,"

[1] Read before the Chemical and Bacteriological Section at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] Water Bacteriologist and Chemist, Laboratories for the State Board of Health, State University of Iowa, Iowa City, Iowa.

[3] Johnson, Proceedings American Water Works Association, **33**, 399 (1913).

presented to this Association in 1913, or the able paper of Morse and Wolman[4] on "The Practicability of Adopting Standards of Quality for Water Supplies," read before this Association in 1918. Instead of so doing, the author hopes to take up the matter from a rather different angle, and to discuss that which, aside from physical attractiveness, is essential to a good or satisfactory water supply.

In so doing, the author realizes the immense difficulties of the question, the bias which experience with the waters of any particular class is likely to give the worker whose observation has been limited, and the practical futility of any attempt to give an entirely definite, clear-cut and readily understandable explanation of the question, so puzzling to many public officials, city councils, and health officers, as to what really is necessary in a satisfactory water supply, when judged from analytical results and similar data.

The confusion is not of recent origin. It is easy to find judgments based on misconceptions or irrelevant or insufficient data. Pliny, for example, seems to have been a bit confused when after declaring that the lightest (and hence softest) water is best, he yet insists that the freezing of a water removes the most refined parts and that water from melted ice is very bad to drink. He goes on, however, to say that boiling is generally admitted to improve the wholesomeness of water and that the best corrective of unwholesome water is to boil it down one-half, a rather heroic treatment.

A text book for health officers, published in 1919, after carefully avoiding definite numerical statements as to the maximum allowable amount of nitrites and so on, gives the following, relative to total solids: "A water containing over 500 parts of total solids per million is not considered fit for household use. Water of good quality usually contains less than 100 parts per million."[5]

To the author's mind, this statement simply illustrates the danger of generalizing too broadly on the basis of experience in a particular locality. To be sure, excessive mineralization is objectionable and finally gets to such a point in some places that the water cannot be used. There are, however, many places where waters of much over 500 parts per million of total solids have been in use for long periods of time without ill effects upon the human organism, whatever the effect on steam boilers may be. Instances might be

[4] Morse and Wolman, Journal of the American Water Works Association, 5, 198 (1918).

[5] Overton and Denno, The Health Officer, 1919.

multiplied where undue emphasis seems to be put on a factor, such as the softness of a water, which, instead of being a necessary condition, is merely a desirable one.

The author is indebted to Charles R. Henderson, of the Davenport Water Company, for a reference to an old scheme for judging water, translated from the French of Fourcroy, and published in Edinburgh in 1784. It is said that

> Drinkable waters may be easily known by the following character:
> (1) They have a brisk, sharp taste.
> (2) They have no smell.
> (3) They boil easily.
> (4) They make ready pot-herbs well.
> (5) They dissolve soap without forming lumps.
> (6) They deposit nothing or very little by tests.

This is something rather more elaborate than was evidently in the mind of the Mississippi jurist, quoted by Mason,[6] who was of the opinion that any ordinary mortal knew whether or not a water was safe to drink.

Of course experience had shown the folly of such an attitude long before the judge gave his opinion of such matters. A scheme of chemical analysis had probably long been built up. In 1867 when Wanklyn[7] developed the albuminoid ammonia process, a procedure seems to have been quite generally in vogue, although Wanklyn claimed that his book, published in 1868, was the first book published on water analysis. Wanklyn felt that for most purposes a sanitary analysis was complete when it included total solids, or specific gravity, chlorine, free and albuminoid ammonia, oxygen consumed and poisonous metals. He felt that a bacteriological examination was of very little use and that the chemical examination alone was sufficient to pass or condemn a water with very little risk of failure. The rules for the interpretation he said were "tolerably simple."

But the simplicity of the system which Wanklyn proposed, based chiefly on a very dogmatic interpretation of the results of his albuminoid ammonia determination does not meet with general approval at the present time. The determinations have been increased somewhat, but the procedures have increased in number even more.

[6] Mason, Science, 21 (New Series), No. 539, 648 (April 28, 1905).
[7] Wanklyn, Journal of the Chemical Society, **5** (Series 2), 593, 1867.

Thus, on account of the lack of uniformity of methods, an attempt was made to standardize methods of water analysis as early as 1887 by the American Association for the Advancement of Science.[8] This work seems to have been suggested by a paper of Prof. W. H. Seamon before the Chemical Section of the American Association for the Advancement of Science at Buffalo.

In a sense this report and one or two which followed were the forerunners of our present "Standard Methods of Water Analysis," now gotten out by the American Public Health Association. The present methods, according to the preface of the first edition, apparently resulted more directly from the efforts of Dr. Wyatt Johnson, of Montreal, who was active in the work from 1894 until his death in 1902.

The first appearance of "Standard Methods of Water Analysis," in book form was in 1905. The fourth edition is just off the press within the last few months. The Standard Methods, as everybody knows, consist of sections devoted to chemical, bacteriological, and microscopical examination. The last named is by far the shortest section. These methods have generally been in accord with current practice and have done a great deal toward unifying the procedure in water laboratories. In 1905 a scheme was proposed outlining the tests that the committee deemed necessary for various waters, based on the character, variety of treatment, and so on. Recent inquiries have shown that the procedure in the state[9] and city and water works[10, 11] laboratories is still far from uniform. The greatest variation is, naturally enough, along the line of the bacteriological examination. Here, the manner of obtaining bacterial counts and the tests employed for the members of the B. coli group are varied over a rather large range. However, the media employed seem to be generally prepared according to the "Standard Methods of Water Analysis."

The public, officials, and to a large extent the physicians, still persist in the belief that a water examination is much like an analysis of an iron or steel, and that the less the analyst knows about the source and nature of the sample, the more reliable his work will be.

[8] Caldwell, Journal of Analytical Chemistry, **3**, 398 (1889).

[9] Morse and Wolman, Journal of the American Water Works Association, **5**, 198 (1918).

[10] Hinman, Journal of the American Water Works Association, **5**, 133 (1918).

[11] Norton, Journal of Infectious Diseases, **23**, 344 (1918).

Every water analyst occasionally receives water samples in containers which range from 2 drachm vials, through perfumery bottles, medicine bottles, mason jars, and jugs to 5 gallon demijohns. Formerly the whiskey flask was a favored receptacle. Every imaginable degree of care in the preparation of the containers, from actual sterilization to a mere rinsing, could be expected.

Occasionally deliberate "doctoring" of samples of water for examination is practised. The author remembers one case in which urine was added to a sample of well water in the hope that the water might be condemned, and the owner of the property be forced to put in the more convenient city water. In other cases various materials have been added to samples of city waters, sometimes by city councilmen, as continued good reports upon the city supply caused the analyst to be suspected of collusion with the water department to provide reports invariably satisfactory.

The difficulties in the path of the analyst are great enough, even under the best conditions of collection, an accurate description of the source of the sample, and prompt examination. While the value of the sanitary survey has been admitted for a very long time, it has been, and still is, the practice of many State Boards of Health to let the sanitary survey, if it can be called such, be made by the sender of the sample who may, by long association with conditions or lack of appreciation of sanitary matters, be totally unfitted to transmit correct information to the laboratory. This is, of course, practised, in most cases, because of small appropriations and a desire to extend the work to as many of the citizens of the state as possible. The practice has been condemned by many workers and Whittaker[12, 13] has shown the chance of error to be relatively great. It is undoubtedly true that in order to obtain the most reliable results, a sanitary survey of each supply should be made and the samples of water collected at the same time by a trained observer. The examination of the water should be begun at the earliest possible moment and the results of the analysis should be interpreted in the light of all the information available.

Fixed standards are at best reversions to rule-of-thumb methods, since they attempt to pronounce a judgment upon a water supply, while utilizing only a part of the evidence. They are demanded

[12] Whittaker, American Journal of Public Health, **7**, 785 (1917).

[13] Whittaker, Journal of the American Water Works Association, **7**, 278 (1920).

chiefly by the non-technical public on account of the convenience in enforcing legal measures, such as control of water supplies and the guarantees of filter manufacturers.

Standards may be divided into three groups on the basis of the way in which they approach the matter in hand:

1. Ideal standards. Those which are intended to give the values which would be found on an analysis of a water of great natural purity. An example of this sort of standard is the standard of the Hygienic Laboratory of the University of Michigan.[14]

2. Normals. These are standard values which have been found to be characteristic of pure waters from similar sources in areas more or less narrowly restricted and from approximately the same geological horizons. An example of this type may be found in the local standards of Haines for water on the west bank of the Delaware River near Philadelphia.[15]

3. Limit standards. These are standards expected to show the maximum amounts of various matters permissible in waters. There are many examples of this sort of standard. One of the most typical sets of standards is Bartow's suggested limits for Illinois waters.[16]

It is necessary, of course, that it be well understood what sort of a standard is meant. Ordinarily we think of limit standards when the word standard is used. For the normal type, the words, normal or normal value, should be sufficient.

The normals to be true values must be obtained by the summarizing of a long series of analyses of waters which clinical experience, sanitary survey and all other data show are typical unpolluted waters of the region. Just how large an area should be included in the determination of the normals would of course depend on the local circumstances. One recent report involved the determination of isochlors for an area of more than 20,000 square miles on a basis of the examination of only 62 samples.[17] Depth, or preferably the geological horizon, should be known for all well water sources, as this information may be more important than the areal distribu-

[14] Vaughan, Public Health, Michigan, **7**, 9 (January–March 1912).

[15] Haines, Journal of Analytical and Applied Chemistry, **5**, 289 (May 1891).

[16] Bartow, Bulletin of the University of Illinois, Water Survey Series, No. 7, 109 (1909).

[17] Vickery, Proceedings and Transactions Nova Scotia Institute of Science, **14** (iv), 335 (1917–8), through Chem. Abstracts **14**, 1719 (1920).

tion. Normals cannot usually include bacterial results when dealing with more than one supply, although the relatively great bacterial purity of ground waters must be noticed.

In the matter of limit standards, both chemical, bacteriological and combined standards have been proposed, adopted and made part of ordinances, regulations of State Boards of Health, and given the force of state statutes. Sometimes they have been made after considerable experiment in a particular locality, sometimes after consultation with experienced workers, sometimes apparently in a purely arbitrary manner. Sometimes the standard has been made for one particular supply and sometimes a general standard has been attempted. Generally speaking, a local standard is of very restricted interest, but when a standard is applied to the waters of a state or country, especially our own, it is a matter of vital importance to the men of the water supply industry.

Nevertheless the making of local standards, accompanied by penalties is of general interest. Sometime ago Jordan[18] called attention to City Ordinance 1769, of the City of Des Moines, Iowa, passed January 11, 1911, and City Ordinance 7113 of Omaha, Nebraska. The Des Moines supply is a chlorinated infiltration gallery water and the Omaha supply is river water, coagulated, settled, and chlorinated. After a period of three months in the case of Des Moines and fifteen months in the case of Omaha, the water furnished was required to meet the following conditions:

	DES MOINES	OMAHA
Total solids	450.0	475.0
Free ammonia	0.04	0.04
Albuminoid ammonia	0.10	0.05
Oxygen absorbed in 10 minutes at 100°C	2.00	2.00
Chlorine	3.5	
Nitrogen as nitrites	0.00010	None
Nitrogen as nitrate radical (NO_3)	0.75	
Bacilli per cubic centimeter	50.0	50.0

The water must be clear without suspended matter and free from "any gas-producing bacteria, colon bacilli or other pathogenic bacteria."

[18] Jordan, Proceedings Indiana Sanitary and Water Supply Association, 8, 94 (1915).

The Des Moines ordinance carried a provision entitling the City Council to make examinations when desired but requiring examinations to be made at least once a week. The violation of the ordinance was made a misdemeanor, punishable by a fine of $100 or by imprisonment not exceeding 30 days in jail. Each day unsatisfactory water was furnished was to constitute a separate offense. This is the most complete set of local standards which have been duly enacted, so far as the author is aware.

Neither the Des Moines nor the Omaha ordinance specifies what media or temperature shall be used for the bacterial counts, though the ordinances specify that the methods of the American Public Health Association shall be used, and that lactose bouillon shall be used for fermentation tests.

The Des Moines and Omaha waters are treated waters, so that the bacterial results, and not the amounts of chlorides and nitrogen, are essential information in judging the quality of the water. Everybody knows that the Raccoon and the Missouri are polluted rivers. The chlorides of the raw waters and the vagaries of the nitrogen determinations are quite beyond the control of the plant operators. Then, too, while at least one writer has claimed to be able to determine the number and class of the bacteria present in a water by the nitrogen factors, the author believes that most water analysts would consider the process open to the criticism that it at least lacked accuracy.

Whatever the framer of the ordinances has in mind with regard to the practical working of the proposed standards, had the nitrogen determinations or the determination of the chlorides been at any time above the values set forth, the water would not have been of "standard quality." Then those in charge of the water works might have been forced to face the penalties as specified in the ordinances or else show that the ordinances were not valid. In either case the effect upon the public opinion would have been much the same.

These standards were adopted about three years before the author had had any experience with water supplies in that particular part of the country, and he has little personal knowledge of the actual enforcement of the ordinances. The ordinances have been introduced here solely to illustrate the point that legally established standards of this nature may be impossible of fulfillment, and, unless interpreted with so great leniency as to be practically worth-

less, may result in the condemnation of a supply which is entirely safe. Moreover, standards of this sort may easily constitute an element of offence in the hands of unscrupulous persons, who may wish to discredit the water supply.

In the case of table waters which are put upon the market with special claims as to purity, or perhaps as to their mineral contents, any material departure from the purity or mineralization claimed, may constitute an offense under pure food laws. The United States Department of Agriculture standard, of which more will be said later, was prepared for the purpose of regulating the purity of table waters, and prosecutions are brought against dealers whose waters do not come up to the requirements. This standard has the same bacterial requirements as the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic, but it also carries certain chemical provisions, "special significance being attributed to the presence of nitrites, free ammonia in excess of 0.05 milligram per liter and to an undue amount of organic matter." Since most states have adopted the food standards of the United States Department of Agriculture as their own standards, this standard for table waters automatically becomes their standard also.

Article 1935 of the city code of Evanston, Illinois, contains a local standard for table waters: "No water shall be sold or offered for sale for drinking or other domestic purposes which contains sewage forms or pathogenic bacteria or contains more than 100 bacteria per cubic centimeter in a total seven day count at a temperature of 20 degrees centigrade on agar or which contains nitrates or nitrites in such amount as to indicate contamination as ascertained by the standard methods of water analysis." The penalty is a fine of not less than $10 nor more than $200.

Local standards of plant operation are in most cases fundamentally different from the standards given above. They may never be written down at all, but may exist only in the mind of the operator in charge. These plant operation standards represent what the operator in charge expects of his plant in the light of its past performance, treating the water regularly handled. The local source of the water, the peculiarities of the plant, and the operator's own knowledge of current water works practice are usually the determining factors. Naturally, standards of this type for water plants vary widely. Some operators are apparently satisfied if the water

pumped is "bright and clear," others demand freedom from iron, a certain maximum hardness or a high degree of bacterial purity. Tabulations in the author's paper[19] on "American Water Works Laboratories" contain lists of these lower operation standards. It is in the smaller plants where we may expect to find the local operation standards at the lowest values. Commonly a reasonably clear water is satisfactory to the operators of many of these plants unless the State Board of Health or some other agency calls their attention to their delinquency.

Local operation standards frequently contain the obsolescent term, "percentage of bacterial removal;" sometimes the "B. coli index." At times the index is calculated upon a few samples; at other times it is based upon the examination of an adequate number of samples with sufficiently great variation in the size of the portions tested for the colon group organisms. Sometimes the colon tests are mere presumptive tests; at other times all gas-forming bacteria are subjected to complete identification tests. The importance of the latter, will, of course, depend upon the local experience, being greatest where the atypical gas-forming bacteria are found much more frequently than the true colon-type organisms. Likewise the complete identification is more significant in gas-forming bacteria isolated from treated waters than in those isolated from ground waters where either type indicates a contamination presumably from the surface. It is perhaps not amiss at this point to insert a table of results upon an Iowa city water which is both filtered and

WATER	TEST	NUMBERS OF TUBES				
		0.01 cc.	0.1 cc.	1 cc.	10 cc.	Total
Raw	B. coli	9	33	143		185
	B. aerogenes	1	4	30		35
	Other gas-formers	5	6	28		39
	Negative	38	25	144		207
	Total	53	68	345		466
Treated	B. coli			2	5	7
	B. aerogenes			0	4	4
	Other gas-formers			1	59	60
	Negative			642	260	702
	Total			645	328	973

[19] Hinman, Journal of the American Water Works Association, **5**, 133 (1918). The author has also filed recently with the Secretary of the Association blueprints giving a more complete record of local operation standards.

chlorinated. The difference in the character of the gas-forming organisms in the raw and treated waters is readily apparent, as has been noticed by other observers with other waters. Differentiation between Bacillus coli and Bacillus lactis aerogenes was made by means of eosine methylene blue agar plates.

The value of the B. coli index calculated upon the presumptive test alone would be a rather different value from the index calculated upon the confirmed test.

The author does not believe with Wells[20] that the fact that much of the mathematical work on the probable numbers of bacteria or B. coli group organisms has been done by engineers accustomed to higher mathematics will cause bacteriologists to neglect this sort of work, or to fail to attempt to understand and apply the principles involved. He does believe that the remarks of Doctor Mason[21] regarding the small value of elaborate calculations based on insufficient data or a few samples, involving large probability of individual error, should be kept in mind. The author particularly objects to the practice, to which he has of necessity at times been a party, of figuring the number of B. coli type organisms per 100 cc. on the basis of the examination of one or a few samples of water collected from a railroad supply during the six months period specified.

It is only fair to Phelps, the author of the system commonly used for calculating the B. coli index in the United States, to note that in the original article[22] Phelps definitely stated that his method was of value only for work involving large numbers of samples from a single supply, and that for a single sample or for a few samples it was worthless.

The work of Whipple,[23] Wolman,[24] McCrady,[25] Greenwood and Yule,[26] Stein[27] and others is highly significant of the trend of

[20] Wells, American Journal of Public Health, **9**, 956 (1919).

[21] Mason, Journal of Industrial and Engineering Chemistry, **11**, 486 (1919).

[22] Phelps, Proceedings American Public Health Association, **33**, 9 (1907).

[23] Whipple, Journal of the Franklin Institute, **182**, 37 (1916).

[24] Wolman, American Journal of Public Health, **6**, 1153 (1916). Journal American Water Works Association, **4**, 200 (1917). Journal American Water Works Association, **5**, 272 (1918).

[25] McCrady, Journal of Infectious Diseases, **17**, 183 (July, 1915). Public Health Journal, **9**, 201 (May 1918).

[26] Greenwood and Yule, Journal of Hygiene, **16**, 36 (1917).

[27] Stein, Engineering News-Record, **82**, 1106 (1919). American Journal of Public Health, **8**, 520 (1919).

ideas on water examination. The mathematical summarizing of results of water examinations and of plant operation is the subject of a large amount of endeavor. Something useful is bound to come of it ultimately. The problem involves two apparently opposed types of data. What we need, of course, is a system which will enable us to grasp quickly, but accurately, what sort of results a particular plant is giving in operation, but its response to unusual or accidental conditions is of great importance, and the value of the information obtained at such times should not be destroyed by smoothing to a general average.

The possibility of accident in water works operation is a tremendous subject, not without its bearing on water supply standards. In this connection the author does not mean stoppage of the pumps or the breaking of a main. It is accidents involving the quality of the water itself to which reference is made, for, as Houston[28] has recently said, "it is obvious that to allow any adventitious water to enter a water supply subsequent to its purification is fraught with potential danger, and danger which even the most astute expert may be powerless to gauge." The care and expense employed in purifying a water supply are largely wasted if the purified water is subject to contamination by means of connections to impure private water supplies, by leakage into reservoirs or clear-wells, by careless storage, or other conditions which follow faulty design or construction. Lists, such as that of the Minnesota State Board of Health,[29] setting forth some of the commonly found defects of construction are suggestive.

When we attempt to consider a question such as this, we find ourselves at once confronted by the question of the standardization of the sanitary survey. The work that Horton and Chase[30] have done on the scoring of water supplies in New York State and the suggestions of Wolman[31] relating to a possible index number system for rating water purification plants are interesting, if not of general applicability at the present time.

[28] Houston, Reports on the Progress of Applied Chemistry, Society of Chemical Industry, **4**, 477 (1919).

[29] Report of the Division of Sanitation, Minnesota State Board of Health, 1916–17, page 367.

[30] Horton and Chase, American Journal of Public Health, **7**, 380 (1917).

[31] Wolman, Journal of the American Water Works Association, **6**, 444 (1919).

Surveys are not now standardized, of course, but even so, their value cannot be questioned. It has long been appreciated that if the possibility of pollution of a supply can be detected by a survey, an analysis, other than to attempt to determine the strength of the contamination, is usually unnecessary. Whittaker[13] has shown that unsatisfactory conditions are often more successfully detected by the survey than by the analysis of the water, although the latter has its own definite importance.

The possibilities of intermittent pollution of ground waters, at intervals separated by periods when analyses may yield satisfactory results, and the variation of efficiency of purification at most water purification plants must be recognized. An analysis may tell what the condition of a particular liter or gallon may be, but that gallon or liter was collected at a particular moment, on a certain day, at a particular place. There is oftentimes a very strong probability that the sample as taken did not represent, in an exact fashion, the water being supplied all over the system at the time the sample was collected, and that the variation over a period of a year might be very great indeed. But the sanitary survey may help in securing samples more truly representative than samples taken without due regard to the peculiarities of the supply and, even more important, it may point out the possibilities of future difficulties, with possible suggestions as to the removal of the danger before anything of a serious nature has developed. It is, indeed, very doubtful if any supply should be passed or condemned without a thorough sanitary survey. It is quite as important in judging a supply to know that the water is produced and distributed in such a manner that periodical variation or accidental contamination cannot be expected to prejudice the quality of the water, as it is to know that one or more samples submitted to analysis show nothing to indicate that anything dangerous to health is present in them.

For the information of the Committee on Official Standards of Water Analysis of the American Water Works Association, and for the preparation of this paper, the author has recently made an inquiry of a number of city, state and plant authorities as to their experience with water supply standards. A large amount of information was courteously furnished which has been summarized in two tables. Table 1 details the results having reference to the State Water Laboratories, and Table 2 details those referring to the plant and city laboratories. Copies of these tables have been filed with the Secretary of the Association.

Of the state water laboratories six apparently use the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic: three use more rigid standards, but one of these is readily modifiable: seven use the United States Treasury Department standard or its variant, the United States Department of Agriculture standard, but not in a hard-and-fast manner: seven use less rigid standards; nine have no standards at all; three were not definite enough in their statements to permit classification into one of the above groups. It is in these state laboratories that one would expect to find the greatest use of standards, because they offer an apparently satisfactory means of distinguishing good from bad water supplies, and offer something of a tangible nature for the making of rules and regulations, and the control of public water supplies.

It is hardly worth while to define the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic.[32] (Not more than 100 bacteria per cubic centimeter in 24 hours at 37°C., on agar; not more than two out of five 10 cc. plantings positive for B. coli group organisms. Media used according to Standard Methods of Water Analysis, A. P. H. A., 1912.) The United States Department of Agriculture standard is perhaps less well known. Its provisions have already been given.

When the bacteriological standard of the Treasury Department was adopted on October 21, 1914, as the work of a commission of experts, it was proposed to follow it with a chemical standard. This was later abandoned as impractical on account of the difficulty of securing an agreement upon the factors to be used. Hanford and Bartow[33] published a suggested set of chemical standards based upon experimental work on railroad water supplies in Illinois.

At the time the Treasury Department Standard was adopted it was expected to use it as a hard-and-fast laboratory standard setting the maximum amounts of bacterial content permissible. Judgment was to be made based upon one sample of water, taken from the water tanks of trains and other sources which would preclude a sanitary survey of the source. The amendment of 1919,[34] which

[32] United States Public Health Reports, **29**, No. 45, 2959 (Nov. 6, 1914).

[33] Hanford and Bartow, Bulletin of the University of Illinois, **14**, No. 5, Water Supply Series No. 13,256 (October 2, 1916).

[34] Amendment No. 8 to U. S. Interstate Quarantine Regulations, July 14, 1919.

requires a survey, is sufficient evidence that, although it was felt at the time of the promulgation of the standard that a rigid enough standard had been devised to allow for all conditions, it was found that the standard was open to error. The recent statement of Senior Surgeon J. O. Cobb, United States Public Health Service, before the Indiana Sanitary and Water Supply Association[35] is significant of the newer trend of official ideas on the subject of the standard:

> Water supplies heretofore have been passed upon by bacteriological standards. Very little attention has been paid to survey standards which engineers would likely set. I think the time has come to adopt the engineering point of view. The bacteriologist will only be a checker-up and I think I can convince you . . . . that we should adopt the survey method of accepting a water supply rather than the bacteriological.

This is a decided change of front over the original method, and one which seems to the author to be more logical and more likely to meet with the approval of plant operators, whether or not their supplies will pass the requirements at the present time. The Treasury Department standard is of interest to every water works operator in the United States, for although it was announced in the original notice that the standard was to be applied only to the water supplies used by railroads which had the opportunity to fix their points of filling tanks, and were not compelled, as the municipality might be, to take the water at hand for use, the effect of the posting of notices in stations and the condemnation of local waters has been to force the standard upon the local plants through the action of governmental prestige and public opinion. In so doing the standard has been useful in raising the quality of some water supplies, though it may have worked hardship upon some satisfactorily conducted plants. It was the author's understanding that the standard was to be applied only to the supplies from which interstate carriers took their water. It now appears, however, that the Public Health Service expects to control supplies of carriers whose lines do not cross state borders on the ground that they may carry interstate passengers and become in effect interstate carriers. The basis for this last statement is found in a foot note to a recent report on the

[35] Cobb, Proceedings Indiana Sanitary and Water Supply Association, **12**, 12 (1919).

railroad water supplies of Iowa.[36] If this is correctly understood, the Treasury Department standard will be extended to a large number of additional water supplies.

Of the 168 city plants from which reports were received by the author, 46 claim to operate continuously to the Treasury Department standard, 4 work to a more rigid standard; 16 work to a less rigid standard; 45 do not claim a standard and 44 give standards whose position with respect to the Treasury Department standard is difficult to determine.

When it comes to the expression of a direct opinion on the Treasury Department standard, 47 consider the standard reasonable, if those who claim to reach the standard practically 100 per cent of the time are included as considering it so: 19 are in favor of the standard with reservations; 21 are opposed to the standard and 81 express no opinion. The 19 who favor the standard with reservations nearly all wish a standard that is flexible; that will take into consideration the natural advantages and the natural disadvantages of the supply. As the standard of the Treasury Department was originally conceived, this desired flexibility was impossible, but with the amendment of 1919, it is possible that a certain degree of flexibility may be introduced. Several of those who are opposed to the standard base their opposition upon the same point. As the standard departs from its rigidly fixed character under the 1919 amendment it is thus reasonable to believe that it will receive their approval

One man states as his opinion that "if a (fixed) standard is adopted for general application, it must be one which can be met by every water company. Then it would have to be so broad and liberal as to have no real value." It is felt that a standard in its fixed form might be too high for some plants actually furnishing a safe water, and yet be so easily met by certain others that the latter might become too lax in their methods.

Some others who expressed opinions in the matter are even more forceful in their condemnation of the whole subject of standards. For example there are the following statements: "Hire a man who is capable of judging conditions and throw rule-of-thumb methods away," and, "The more I see and hear of so-called standards for water, the less I think of them."

[36] Footnote to Wagenhals' Report to the Iowa State Board of Health on Water Supplies Used for Drinking and Culinary Purposes by Common Carriers in Interstate Traffic, page 2 (February, 1920).

McLaughlin[37] has advocated the application of the Treasury Department standard to the effluents of filter plants prior to their treatment by any germicidal agent, such as calcium hypochlorite or liquid chlorine. This would considerably increase the difficulty of many plants in reaching the prescribed degree of bacterial purity. To be sure it would introduce a large element of safety, probably well worth while in plants suspected of being carelessly operated. Ohio has recently begun the use of a set of standards including one for filtered water before chlorination. This particular standard seems to be, in its essence, the same as that of McLaughlin.

The Treasury Department standard was adopted as the standard of the American Expeditionary Forces in France. Its use there was apparently generally satisfactory. Where unfiltered water was used, it was sometimes necessary to use quite heavy chemical treatment in order to get the water within the specified limits. The experience of the soldiery with Lyster bag chlorination was such, however, that a dose of chlorine which would not be used in city water works practice could be used in France without undue complaint. It was found, too, that the Treasury Department standard in regard to freedom from B. coli group organisms was approximately equivalent to the apparently more rigid French standard. The French commonly used phenol broth for their B. coli tests, instead of lactose bouillon, and the inhibitory action of the phenol was believed to be responsible for the difference in the apparent results.

The International Joint Commission on the Pollution of Boundary Waters, in its study of the water along the boundary between the United States and Canada, employed a tentative standard for reasonable burden on filter plants in so far as the character of the raw water was concerned.[38] This standard, which was adopted on the advice of some of the most eminent engineers of the water supply industry, was an attempt to gauge, in a rough manner, the extent of the sewage contamination of the raw waters which filter plants could be reasonably expected to handle in a satisfactory manner. The standard provided that in order to be a suitable water for filtration, a raw water should not show more than 50 per cent positive tests for the B. coli group organisms when 0.1 cc. quantities were

[37] McLaughlin, U. S. Public Health Reports, **29**, No. 26 (June 26, 1914).

[38] Final Report of the International Joint Commission on the Pollution of Boundary Waters, Washington, 1918, page 14.

considered and frequent examinations were made to determine the character of the water over the period of a year. Thus it would correspond to a yearly average of 500 B. coli group organisms per 100 cc. This standard as a tentative limit of reasonable burden, could not be said to be a fixed standard of the character of the United States Treasury Department standard for water supplied by interstate carriers.

There are those who see in the present apparently chaotic state of water supply standards the result of attempting to build a structure involving the use of absolute values, upon a foundation of determinations which, as Bertarelli[39] has said, have often only a purely doctrinal value. The actual causative organisms of water-borne diseases, with the possible exception of the Vibrio cholerae, remain elusive to methods of detection which are sufficiently simple, rapid, and accurate to permit of their use in routine water examinations. Elaborate generalizations, such as those of Kinnicutt,[40] based on the nitrogen determinations, have been attacked in such papers as that of Leighton[41] on the Futility of a Sanitary Water Analysis. And yet we have available tools, in our methods of water examination which, though perhaps open to error if incorrectly used, are nevertheless, good and useful and capable of giving us valuable information.

We must not allow the good points of the methods that we have to be obscured by the fact that under certain circumstances they do not fit the conditions. In the case of determinations which are most useful in following the condition of raw waters, chemical methods, if applicable, can avoid the loss of time which as yet cannot be avoided when dependent on bacterial methods. In different places it is natural that different methods are followed as most satisfactory. Thus Calvert[42] says that for distinguishing one water from another or detecting any important change in the mixture of waters at the plant of the Indianapolis Water Company, the determinations alkalinity, chlorine and nitrites are most useful. At

[39] Bertarelli, Rivista di Ingeneria e di Edilizia Moderna, **16**, No. 21 (Nov. 15, 1915) through Bulletin Mensuel Office International de l'Hygiene publique **8**, No. 2, 386 (1916).

[40] Kinnicutt, Science, **23**, New Series, No. 576, 56 (January 12, 1906).

[41] Leighton, Biological Studies by the pupils of William Thompson Sedgwick, Boston, 1906, page 36.

[42] Calvert, American City, City Edition, **22**, No. 6, 576 (June 1920).

another plant alkalinity and iron are the most useful, at another the free ammonia is depended upon, and at another the oxygen consumed is considered to give the best indication of changes of importance in the raw water. These determinations are especially useful where waters from the various sources are practically clear and colorless. Where mixtures of streams of decidedly different color and turbidity are handled, the value of the color and turbidity measurements is self-evident. For general purposes different workers consider different methods preferable. This is natural, of course. Some hold tightly to the orthodox nitrogen determinations, while others discard them, claiming that they have no value. But the fact that these determinations have no value in one locality may not destroy their usefulness in another. It is when these determinations, whether of the nitrogens or other factors, are applied to general fixed standards that the great likelihood of error arises.

Bacterial counts and determinations of the B. coli group organisms are useful, too. Many analysts would undoubtedly say that they constitute our chief tools in determining the sanitary quality of a water. But they, too, are liable to a certain amount of error in the hands of those who are unfamiliar with local conditions. In the South, or where the temperture approaches the body temperature, rapid aftergrowths of the organisms originally present in the water and surviving chlorination, and also the multiplication on storage of the few organisms present in well waters, may be expected. This is in line with the statement, made many times before, that while the actual number of bacteria in a water is of value in judging the water, high bacterial counts are not necessarily associated with dangerous, or even objectionable, contamination. Haskins,[43] among others, has objected to too great emphasis on the B. coli group organisms, especially when these forms seem to be restricted to soil and grain types, and the sanitary survey shows no probable source of pollution. Then there are the spore-bearing gas-formers to be considered, with the reduction in the value of the unconfirmed presumptive tests in the localities where these forms are predominant. With a fixed standard in use, proper provisions for these matters is difficult, to say the least.

Standards, if prepared, must have a certain amount of flexibility and depend in large part upon the sanitary survey as made by

[43] Haskins, Engineering News-Record, **78**, 312 (1917).

someone who is experienced in such matters. And the object in view must be to get a safe water, from a suitable source, in a manner which represents the best operation of the plant. It is the author's belief that the greatest possibilities along the line of standards are in the direction of purification plant operation and construction.

In spite of its general character, the author feels that in closing this discussion it is well to repeat the definition of a satisfactory water which was proposed by the Association's Committee on Official Standards of Water Analysis:

> A water which is reasonably free from noticeable color, odor, taste, and turbidity, which is reasonably free from objectionable salts in solution, which is free from injurious effects upon the human body, and which is produced and distributed in such a manner that its quality is practically certain to be maintained continuously in spite of accidents which can be expected in the operation of the plant.

THE EXPERIENCE OF THE MONTREAL WATER AND POWER COMPANY IN THE MANUFACTURE OF FILTER ALUM[1]

By James O. Meadows[2]

The filter alum manufacturing plants of Columbus, Ohio, Springfield, Mass., Trenton, N. J., and Omaha, Neb., have been described in detail in *Engineering News Record* of January 4 and 11, 1917. As the general make-up of all Hoover process alum plants is somewhat similar, it is not intended to describe the Montreal Water and Power Company's plant in detail but rather to give the experience of the past four years of operation.

The alum plant was installed with the idea of keeping the capital outlay as low as possible consistent with proper operation, because at the time it was thought that the plant would only be used for a comparatively short period of time. The plant consists of an acid storage tank, a dilute acid tank, bauxite weighing hopper, Stedman mixer, and concrete crystallizing tray. No crusher is provided, the filter alum being broken up into suitable sized lumps by hand sledges.

The manufacture of Hoover process filter alum is simple, but like every simple thing there are several necessary conditions that need to be carried out to secure the product desired. By varying the temperature of the dilute acid the character of the alum can be modified. During the winter months a porous alum is desired, because of its greater solubility, and this product can be obtained by mixing the bauxite with a low temperature acid. During the balance of the year a filter alum of a more dense texture is secured by using a higher temperature acid. The temperature of the crystallizing tray floor is also a factor to be considered, and it is necessary to use a higher temperature acid for Monday's batch because of the lower temperature of the tray floor after the Sunday rest. The temperature of the acid is controlled by agitating it with com-

[1] Read before the Montreal Convention, June 22, 1920. Discussion of this paper is desired and should be sent to the Editor.

[2] Sanitary Engineer, Montreal, P. Q., Canada.

pressed air and with a cooling coil placed at the bottom of the lead-lined dilute acid tank. By using the air and cooling coil for different periods of time, a dilute acid of the desired temperature can be obtained.

In securing a uniform product from day to day, care must be taken to have the acid strength uniform, the temperature variations slight, and the weight of the bauxite charge correct. The analytical work necessary to control the operation of the alum manufacturing plant consists of the analysis of the bauxite, acid and finished product, and the taking of the specific gravity and temperature of the dilute acid before a batch of filter alum is made.

A batch of alum (approximately 7600 pounds) is made in five mixes, using about one-fifth of the material for each mix and the time consumed in mixing a batch of alum is about three-quarters of an hour. Greater speed in mixing could be obtained if a mixing pan with a deeper pan and two agitators had been installed; also, a better mixture of the bauxite and acid could have been obtained. The batch of alum is usually made early in the afternoon and by the next morning the alum cake is ready to be removed from the crystallizing tray. Before the mixture of bauxite and acid is dumped into the tray, the fine alum dust remaining in the tray is swept up into a ridge extending directly across the tray and to a height of about 2½ inches. When the alum cake is to be removed from the tray, work is started at the alum dust ridge as this point offers an easy place to pry the slabs of alum from the tray floor. The alum cake is removed from the floor with bars and picks and is broken up with hand sledges. The whole process, including carting to the storage floor above, consumes about six hours.

Records of the alum making plant for the past two fiscal years ending May 1 last have been taken off, as during this period the cost of bauxite and acid have been rather constant and it was thought that data covering this period would be fairly representative of present conditions.

The cost of production for this two years' period is as follows:

Bauxite and acid (Including freight and cartage)	$45,961
Wages	4,220
Maintenance	1,490
Interest and depreciation, 20 per cent per annum	2,400
Total	$54,071

During this two-year period, 1888 tons of filter alum have been produced, making the cost work out at $28.64 per ton. The market price of commercial filter alum (including freight and duty) during this period has been about $55 f. o. b. Montreal, and, based on this figure, the alum-making plant has shown a saving of slightly more than $49,000 for the two year period. During this time bauxite has cost approximately $24 per ton and 66° Baumé sulphuric acid $26 per ton. At places where these two materials can be purchased at a lower figure the cost per ton for filter alum will also be correspondingly lower, because from the cost data presented it will be noted that the cost of bauxite and acid make up 85 per cent of the total cost.

In the manufacturing of filter alum at the point of consumption, freight, bagging and cartage are saved on the water, which makes up about 20 per cent of the finished product. Experience over a considerable period has shown that the weight of the filter alum produced is practically the same as the combined weight of the materials that go to make up the product.

At the company's water purification plant, the alum solution is pumped to the orifice box and from this point flows by gravity to the point of discharge. Since Hoover process filter alum has been used, greater depreciation of the solution pumps, valves, and fittings has taken place, due to the nature of the insoluble matter contained in the alum solution. This depreciation, however, has not been excessive and has not run into an appreciable figure.

The manufacture of Hoover process filter alum has proved successful for the Montreal Water and Power Company because of the saving effected. A further advantage is also gained, as sulphuric acid is produced within a short distance of Montreal and is easily obtainable, leaving only the bauxite to be secured from a distance, and, when secured, each ton of bauxite in storage represents about three tons of the finished product.

DISCUSSION

A. U. SANDERSON: It would be useful to know what percentage of alumina is produced at the plant described in the paper.[3]

[3] At Toronto an alum containing not less than 17 per cent of available alumina and not more than 0.1 per cent of matter insoluble in cold water, is used. The small quantity of insoluble matter prevents deposits from accumulating quickly in the mixing and constant density chambers and the

WILLIAM GORE: It will be interesting to learn what effect upon sedimentation has been caused by impurities in the alum in the Montreal operations. This subject was investigated in some detail at the Toronto filtration plant, using a small mechanical filter, and it was found that the best results were obtained with the most impure alum. This sometimes gave 10 or 15 per cent better bacterial removal in the coagulating basin than the commercially pure coagulant gave. While these sedimentation results with impure alum were better the results from filtration were sometimes worse.

JAMES O. MEADOWS: In the process described in the paper from 17 to 18 per cent of the total product is alumina. At the Montreal plant it is nearer 17 than 18 per cent, because the method of mixing bauxite and acid is not the best possible one.

The impurities in the alum made by the Hoover process will average between 7 and 8 per cent, including insoluble matter. During the early years of operation of the Montreal filters great care was taken to obtain a high-grade commercial alum practically free from iron. Later it was found that in practical operation of the plant with Hoover process alum the water turned out was just as good bacterially as that produced with the less impure alum used originally. Perhaps this maintenance of a high standard is due to greater experience in operating the plant, but it is hardly probable. In experimental work in the laboratory, treating small quantities of water with various strengths of coagulant, the coagulation with Hoover alum has been a little better than that with commercial alum.

connecting pipes, and facilitates operation. A series of laboratory experiments were conducted by N. J. Howard, the bacteriologist in charge of the Toronto Filtration Plant Laboratory, and two distinct grades of alum were applied. In the first group an alum was used containing 17 per cent of alumina and less than 0.3 per cent of insoluble matter, and in the second group the alumina varied between 15 and 17 per cent and contained 10 per cent of insoluble matter. Water was treated with varying quantities of alum ranging between 0.5 and 3 grains per imperial gallon, and was then passed through small sand filters. Throughout the series the results were uniform, the high grade alum giving much higher bacteriological purification.

A MAILING-CASE METHOD FOR LONG-DISTANCE BACTERIOLOGICAL CONTROL OF WATER SUPPLIES[1]

By M. H. McCrady[2]

The absolute necessity of laboratory control of water purification processes needs no argument. The general recognition of such necessity is exemplified in the universal practice of installing a local laboratory in every large purification plant, and in the more recent attempt by some State Departments of Health to train local plant operators to make their own laboratory tests. Probably every State and Provincial Department makes an effort to determine, at more or less regular intervals, the efficiency obtained by the plants under their supervision.

The most generally adopted feature of this laboratory control is the examination of bacteriological samples. Such examinations must be frequent, if they are to answer their purpose effectively. The frequent variations in the quality of the raw water, the limitations of mechanical equipment, and the uncertainty of the human element, all create a demand for as nearly continuous laboratory supervision as economy will permit.

In plants with local laboratory service, the ideal of frequency of examination may be closely approached. Samples may be taken daily or many times a day, as conditions may demand. But for the small plant, without local laboratory service, in charge of a man to whom a purification apparatus often means simply increased labor and responsibility without extra remuneration, the duty of maintaining effective laboratory control is passed on to the State or Provincial Department of Health, and there the problem assumes a real magnitude.

It is needless to dwell upon the difficulties encountered in long-distance bacteriological control of water supplies, the bulky and

[1] Read before the Chemical and Bacteriological Section at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] Chemist and Bacteriologist, Provincial Board of Health, Montreal, P. Q., Canada.

expensive equipment required, the time consumed in preparing this equipment for shipment, the cost of shipment, the demand for co-operation on the part of the local man who is to collect and ice the samples, and last, but not least, the expenditure of time and labor in analyzing the samples thus obtained. These difficulties are a common experience to water laboratory men, and their reality is indicated by the infrequency with which samples are usually obtained from plants situated at some distance from the central laboratory.

FIG. 1. DAILY SAMPLING OUTFIT FOR LONG-DISTANCE CONTROL OF WATER SUPPLIES

The mailing-case (A) with screw top (B) fitted with a cardboard partition to hold the four glass tubes.

(C) shows two of the tubes as sent out by the Laboratory. Each contains 2 cc. of concentrated lactose medium.

(D) shows two of the tubes as returned to the Laboratory. The municipal officer has added water up to the mark (L) on the tube from the municipal supply to be tested.

After the water is added to the four tubes as shown in (D), the tubes are replaced in the mailing-case, the date of sampling marked on the case, and the case is mailed to the Laboratory, three cents postage being required.

In the effort to avoid some of these difficulties, it occurred to the author that, by sacrificing to a certain extent, completeness of examination to greater frequency of examination, a method of sampling and analysis might be evolved which would permit of daily or even more frequent sampling, and yet be comparatively inexpensive and demand very little time at either the point of collection or the laboratory.

The object of this paper is to describe briefly such a method, which has been employed for two years by the Laboratory of the Superior Board of Health of the Province of Quebec.

The principle of this method is the daily shipment of samples of water for the determination of the presence of B. coli. The details of the method and apparatus are given at the end of the paper, but the procedure may be indicated as follows: Lots of 20 or 30 small mailing cases are shipped by the laboratory to the town having the water supply to be examined. Each mailing case contains four cork-stoppered glass tubes, graduated at 7 cc., and containing 2 cc. of concentrated medium. Every day the four tubes of one case are filled to the mark by the sample collector with the water to be tested, each tube thus containing 5 cc. of sample, and the case is mailed to the laboratory. At the laboratory a small inverted vial is placed in each tube, the tube tipped in order to fill this vial, and the whole then incubated at 37°C. in the usual manner, results being noted after 24 and 48 hours' incubation. Further identification, in case of positive results, may be practised if required.

Certain features of this mailing method may be noted:

The outfits are inexpensive, for the cases, tubes, vials, etc., are all of standard size, and are readily prepared for use by laboratory assistants.

Time of transit is reduced to a minimum, for the excellent service of the mails is utilized.

Cost of shipment is extremely small, for the case goes through the Canadian mail for the insignificant postage cost of three cents, under the classification of "sample."

The very little labor entailed in the collection of samples ensures a surprising regularity in such collection, and renders it possible to enlist the services of any physician or municipal officer for this purpose.

Check samples from the same town may be multiplied.

At the laboratory a large number of cases may be received each day, for they may be handled at the rate of about one per minute.

A day is often gained in obtaining results by this method as compared with ordinary bottle samples, for, because of multiplication of the organisms during transit, ultimately positive tubes are usually positive after one day of incubation.

Each day's result is quantitative, for the case contains four samples of 5 cc. each, and the total of 20 cc. permits a fairly complete test for B. coli.

Breakage in the mails is an insignificant item, and even when, as has happened once or twice, four tubes were broken, there was no evidence of leakage or stain on the outside of the case, for the liquid is readily absorbed by the paper packing.

Overgrowth of B. coli by other organisms in transit does not appear to be an important factor. Occasionally a case has been received which had been held four or five days, and yet fermentation of an apparently normal character proceeded upon incubation. So far as it has been possible to judge from many control bottle samples and from two or three more extensive comparisons in the laboratory, this mailing method appears to be quite trustworthy, and although results from it may not be so satisfactory or complete as those obtained from bottle samples collected in the usual manner, its inexpensiveness and general applicability have demonstrated its utility.

In the Province of Quebec this system of sampling has been employed for a variety of purposes, but particularly in long-distance control of purification plants it has been of the greatest service. For it is the practice to post, every day, in a chart in the office of the sanitary engineer who is charged with the supervision of these plants, the results obtained. Possession of such a daily record permits concentration of attention on those plants which are really in need of improvement, and in the case of isolated unsatisfactory results, a telephone communication followed, if necessary, by a personal visit to the plant in question, serves not only to frequently discover failures in the mechanical equipment, but also to maintain a lively interest on the part of the operator, an interest further stimulated by receipt of a weekly statement of the results obtained.

To date, the laboratory for this Province has examined over 18,000 tubes of water sent through the mails. These samples have, in the main, come from 15 or 20 different purification plants. Now that further supplies of mailing cases are obtainable, it is intended to extend this service to other plants in the Province.

Two years of experience with this method of sampling and analysis have proved it to be extremely simple and practicable, and the author believes that it supplements, effectively and satisfactorily, the more infrequent examination of the bottle samples usually employed for long-distance bacteriological control of water supplies.

DETAILS OF EQUIPMENT AND MANIPULATION

Mailing case. Metal can, lined with paper board, with screw top.

Outside diameter, $2\frac{1}{4}$ inches; length, $3\frac{3}{4}$ inches; supplied by Improved Mailing Case Company, New York. Extra paper inserts in cover and bottom to absorb liquid in case of breakage.

Partition of double-faced corrugated straw-board to divide the can into four compartments. The paper-box manufacturer who supplies this board cuts it into rectangles 2 x $3\frac{1}{2}$ inches, and laboratory assistants cut and fit the rectangles to make the partitions.

Cans and covers are sterilized before use by dry heat in the usual manner.

Sample tubes. Specimen tubes (shell-vials) flat bottom, straight wall, outside diameter, $\frac{5}{8}$-inch; length, $2\frac{7}{8}$ inches, graduated with a mark at 7 cc. This is done with a pipette, the meniscus marked with a wax pencil, and with a small file wet with water, a cut of about $\frac{1}{4}$ inch in length is made in the glass at the pencil mark. The tube will not break at this mark upon sterilization.

Concentrated medium. This medium may be any that the laboratory may elect, but so constituted that the 2 cc. of this medium, when added to 5 cc. of water sample, will give the required concentration of mix.

Preparation of tubes and cases. The tubes are placed in a zinc rack holding about 48 tubes, and 2 cc. of the concentrated medium is placed, by means of a pipette, in each tube. First-class cork stoppers are then fitted into the tubes, rather loosely to avoid their blowing out upon sterilization. Corks are of the long form, which, when thrust home, will project about $\frac{3}{4}$ inch beyond the tube. A deep zinc box cover is then placed over the rack to keep the corks in the tubes by its weight and to protect the tubes from undue contamination, and the whole then sterilized in the autoclave.

After sterilization, the cover being removed, each cork is firmly thrust into its tube, and the tube placed in its compartment in the mailing case. When the case contains its four tubes, the cover is screwed on, and the label affixed to the body of the case. This label is printed with the address of the laboratory, the word "Sample" to place it in the proper postal classification, and the word "Date" after which the sample-collector is to write the date of collection of samples.

When shipping a lot of cases to a town, a number or group of letters for that town is stamped on the label in order to identify the case upon its return to the laboratory.

Collection of samples. The sample-collector, with usual precautions, fills each of the four tubes of a case with water to the mark on the tube, writes the date of sampling on the label, and affixes a three cent stamp.

Laboratory procedure. Upon receipt of the case at the laboratory, it is identified by the number or group of letters on the label, and the date of collection and of receipt noted on the record sheet. Each tube is removed from the case, its cork stopper withdrawn, and a small vial or specimen tube, having an outside diameter of $\frac{1}{4}$ inch and length of 2 inches, is inserted, inverted, into the tube. (These vials are contained in a beaker, covered with a Petri dish, the whole having been previously sterilized. The vials are taken from the beaker with flamed tweezers.) The cork is then replaced, the tube tipped so that the small vial is filled with the liquid in the tube, and the tube then placed in a wooden rack, which consists of a block 12 x 3 x 1 inch thick, containing four groups of four holes each. The four tubes from the case go into the holes of one of these groups, and the day of collection and day of receipt are written in pencil on the wood near this group of tubes. Each town from which samples are received has its own rack, permanently labelled. The rack is then placed in the 37°C. incubator.

Reading of results. Results are read after 24 and again after 48 hours. At least 10 per cent of gas is required for a positive result, as it is difficult to remove every last small bubble from the vial when the latter is inserted into the tube.

Laboratory record. The record form used by this laboratory is the following:

June, 1920

SHERBROOKE				SOREL			
1	2	1	2	1	2	0	0
2	4	0	0	2	3	1	1

From the above record, a case received from Sherbrooke on June 2, samples having been collected on June 1, had 1 tube positive after 24 hours incubation, and 2 tubes positive after 48 hours incu-

bation. Case sent on June 2, and received on June 4 had no tubes positive after either 24 or 48 hours incubation.

Range of results. The range of numbers of B. coli corresponding to results obtained with four, three, etc., tubes of 5 cc. of sample each, is shown below (as probable numbers of B. coli):

Numbers of B. coli corresponding to different results with one to four sample tubes

4 TUBES		3 TUBES		2 TUBES		1 TUBE	
Positives	B. coli per 100 cc.	Positives	B. coli per 100 cc.	Positives	B. coli per 100 cc.	Positives	B. coli per 100 cc.
0/4	0	0/3	0	0/2	0	0/1	0
1/4	6	1/3	8	1/2	14	1/1	14+
2/4	14	2/3	22	2/2	22+		
3/4	28	3/3	†28+				
4/4	*32+						

* Considered as a 4/5 result, at least.

† Considered as a 3/4 result, at least.

MILWAUKEE EXPERIENCE WITH COMPOUND METERS[1]

By H. P. Bohmann[2]

Milwaukee's experience with compound meters dates from May, 1912, when the Meter Department installed, for service test, a 4-inch compound meter of a reliable make, on the service of the meter repair shop. This service is used solely for the testing apparatus and one hydraulic sidewalk lift. The stream flows on this line are from 3 inches to $\frac{1}{32}$-inch. On April 1, 1920, with a total registration of 3,455,022 cubic feet on the dial of the current section of the meter, and 689,652 cubic feet on the dial of the disc section, this meter was subjected to a weight test and the following results were obtained. On the 2-inch stream size (the largest permissible with present arrangement of testing apparatus) the current section meter showed an accuracy of 100.1 per cent and on the $\frac{3}{8}$-inch stream 96.6 per cent, while on the disc section operation the percentage of accuracy on the $\frac{1}{4}$-inch stream was 100.8, on the $\frac{1}{8}$-inch stream 99.2, on the $\frac{1}{16}$-inch stream 99.2, and on the $\frac{1}{32}$-inch stream 84.4.

In this meter there is a point of alternation or "change over" of stream flow through the current and disc section at about the $\frac{3}{8}$-inch stream. That is, at this point the valve is in a state of suspension or "leakage" and permits the diversion of a stream through each section too small for accurate registration on either. This condition, however, is not of very great concern, as it is not very probable that in actual service use the valve would remain in this suspended position for any period, due to the fluctuation of pressure and variation in consumption.

With a view to determining the relative accuracy of the compound type and the disc type of meters, a test was conducted for a period of one week by installing a 3-inch bronze case meter on the line in conjunction with the 4-inch compound, the compound meter being a sub-meter to the disc meter. The disc meter is one which

[1] Presented at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] Superintendent Water Works, Milwaukee, Wis.

is used as a master meter in conducting field tests and is probably as accurate as any meter on the market of that type and size after some service. This meter previous to the installation showed an accuracy of 100.8 per cent on the 2-inch stream and 98.2 per cent and 85.6 per cent on the $\frac{1}{4}$-inch and $\frac{1}{8}$-inch streams respectively, while it failed to show registration on the $\frac{1}{16}$-inch. At the conclusion of the run the current section of the compound registered 5854 cubic feet and the disc section 2250 or a total compound registration of 8104 cubic feet, while the 3-inch disc meter registration was 6470 cubic feet or a loss through the 3-inch disc meter of 1634 cubic feet or about 20 per cent loss on registration for the week.

When one considers the inability of meters of the various types other than compound of the 3-inch and larger sizes to register the small stream flows, or their considerable inaccurate registration of those streams, the advantage of compound meter registration is very plain. Milwaukee has 515 meters of the larger sizes in the Worthington Piston, Rotary, Velocity and Disc types, 116 compound meters and 9 fire service meters. Notwithstanding the fact that these meters are subjected to annual field tests and held within the capability for registration for the size and type of the meter, one can't help wishing the entire large meter system were of the compound type.

During the past spring the department has, in its annual field tests, conducted tests of 76 compound meters in which the registration of the current section was 251,485,410 cubic feet and of the disc section 32,764,809 cubic feet, a total of 284,250,219 cubic feet. In most instances these meters were on new installations and a few replaced old worn piston and rotary type meters. It is rather hard to compare registration, but assuming these services were all controlled by disc meters, the most reliable accurate meter other than the compound type, and these disc meters were of the same accuracy as the 3-inch disc referred to in the shop test run, there would be a considerable loss in registration through failure to install compound meters.

A shop-test record of new meters of the velocity and compound type, which during the past 4 years have been presented for installation on the services, shows that while the various makes and sizes of velocity meters are accurate (2 per cent plus or minus) down to the $\frac{5}{8}$-inch stream size, the average accuracy of 22 3-inch to 6-inch meters of five meter companies below that stream size is as follows:

Stream, inches	½	⅜	¼	⅛	1/16
Accuracy, per cent	98.4	96.1	76.4	Fails to register	

On comparing these figures with the following record of 13 compound meters of three companies, it will be seen that there is considerable gain in registration by use of the compound.

Stream, inches	½	⅜	¼	⅛	1/16	1/32
Accuracy, per cent	99.6	97.9	101	101.6	98.2	89.2

Some meter companies in an endeavor to overcome defective registration of the large section of the meter, have the operation of the valve regulated to "break" or "alternate" at a stream size of about ⅝ inch or ¾ inch and install a large disc meter to care for the smaller streams. Milwaukee experience has been that the best results are obtained in lowering the breaking or alternating point down to about the ⅜-inch stream for 3-inch and 4-inch meters and ½ inch for 6-inch meters. That is, have the operation of the current meter on these stream sizes, and the disc section on the lower streams, and the use of a disc meter not larger than 1-inch for 3-inch, 4-inch or 6-inch compound meters.

The reason for this is very plain. The purpose of a compound meter is to secure as far as possible registration of the small streams without sacrificing the maximum delivery, and it is well known that meters of the ⅝-inch, ¾-inch or 1-inch size will register more closely than a 1½-inch or 2-inch meter. With the exception of stoppage of registration on some meters by sand, which is apt to occur to a disc meter, very little trouble has been experienced with compound meters. The upkeep of these meters is very little, being confined to small items of disc section repairs or gear trains and bushings in the current section. On the whole, Milwaukee is well satisfied that a goodly portion of the "unaccounted supply" can be accounted for by the use of compound meters on services where the flow is intermittent, or even in premises supposedly using "large flows at all times."

HARTFORD EXPERIENCE WITH COMPOUND METERS[1]

By J. E. Garratt[2]

Experience with compound meters in Hartford so far has been confined to testing and trying out the various makes, with the idea of seeing which are best suited for the various needs to which they must be put. For meters over 2 inches in size compound meters are used almost exclusively, that one being selected which best suits the particular installation. As old installations come to the attention of the department through trouble or regular inspection tests, new compound meters are put in their place or, if possible, compounding valves are purchased with by-pass meters. Names of compound meters appear on the Hartford meter record cards which would startle many of the meter manufacturers.

There is a wide difference between the various makes of compound meters. Each meter maker has his own, of course. One may have the largest capacity of any of a given size but may also have the greatest weight to be handled and require the largest space for setting. Another may require a straight run of pipe on the inlet end in order that it may register properly, and so, although in certain places it may be an excellent meter, yet in other places it may be of no value. A third may be light, compact, well made and easily handled by one man yet of such small capacity that it defeats one of the principal reasons-for-being of a compound meter. Two others may be of about equal capacity and dependability, while one is much heavier to handle yet takes up much less space than the other and one may be dismembered and entered through a small opening through which the other may not pass. So there are many things which are considered in selecting compound meters in Hartford.

The most serious of these considerations is the requirement of a straight entrance run of pipe of the same size as the meter without valves or other disturbing elements. Several makes of compound

[1] Presented at the Montreal Convention, June 24, 1920. Discussion is desired and should be sent to the Editor.

[2] Office Engineer, Board of Water Commissioners, Hartford, Conn.

meters are in no way affected by this consideration but in one or two it affects the registration very seriously. Tests made in this connection of one particular meter gave the results recorded in table 1.

There seems to be the most effect on the registration with 1-foot and 3-foot lengths of straight inlet, while a 2-foot length gives less effect than the 3-foot. Also, the 4.5-foot inlet gives the least effect but even this length does not appear to be sufficient to completely overcome the large effects caused when the elbow on the inlet is turned to the left.

TABLE 1

Percentage registration of 3-inch compound meter with different lengths of straight inlet pipe

METHOD OF LEADING FLOW INTO STRAIGHT INLET	RATE OF FLOW	LENGTH OF STRAIGHT INLET			
		1 foot	2 feet	3 feet	4.5 feet
Straight	A	98.2	102.5	100.2	99.7
	B	97.9	101.5	99.5	100.0
Through elbow turned up	A	98.2	99.3	104.6	99.3
	B	98.2	99.3	104.0	98.9
Through elbow turned to left	A	105.6	101.0	104.0	102.1
	B	104.0	98.3	104.1	102.2
Through elbow turned to right	A	97.2	102.2	100.3	99.2
	B	98.0	102.1	100.0	98.5
Through elbow turned down	A	105.2	101.7	100.5	98.8
	B	104.6	102.1	99.9	98.6

NOTE: A = Rate of flow of about 35 cubic feet per minute; B = Rate of flow of about 20 cubic feet per minute.

To show the effect of a partly closed valve on the inlet side of this meter the tests recorded in table 2 were made, using 2 feet of straight 3-inch inlet, 3-inch valve, short 3-inch nipple, 3-inch coupling reduced to $2\frac{1}{2}$-inch and a $2\frac{1}{2}$-inch hose. The half-closed valve seems to affect results only slightly while the three-quarters closed valve affects results considerably, as might be expected.

There seems to be a point, at that rate of flow where the weighted check valve in the compound meter begins to open, at which the percentage registration of some meters is low. This point varies in different makes of meters. At this same point the loss in pressure

through certain meters mounts very quickly to as much as 10, 15 or even 20 pounds, while beyond this point the pressure loss may again drop to less or continue practically the same until very large flows begin to pass through.

The condition may arise where a compound meter of large size is needed to supply certain uses which come only seldom but where the bulk of the water is used in the region of this disturbed flow through the meter at which rate of flow the registration is low. If such is the case, one make of compound meter whose point of change from small to large meter is not the same as the expected rate of use might be better than another.

TABLE 2

Effect of partly closed valve on inlet side of a 3-inch compound meter

VALVE POSITION	FLOW, CUBIC FEET PER MINUTE	PERCENTAGE REGISTRATION	VALVE POSITION	FLOW, CUBIC FEET PER MINUTE	PERCENTAGE REGISTRATION
Wide open.....	38	99.6	Half closed	35	100.7
Wide open.....	29	100.8	Half closed	26	101.3
Wide open.....	25	101.3	Three-quarters closed	30	103.0
Wide open.....	17	100.5	Three-quarters closed	18	102.2

An interesting experience was had while installing a compound meter to supply a high building on the top floor of which was a restaurant. The architect of the building persisted in his demand for a large meter, exaggerated his requirements, and the department could do nothing else than install a 3-inch compound meter. It was of a type whose pressure loss quickly mounts to about 10 pounds at a rate of about 1.5 cubic feet per minute and then quickly drops back to about 2.5 pounds and from that gradually increases again, with big flows reaching a loss of 10 pounds again at a rate of about 20 cubic feet per minute. Under actual operating conditions water was used in the restaurant at rates close to 1.5 cubic feet per minute at which rates the pressure loss in the meter was about 10 pounds. It so happened that at certain times during the day, previous to the installation of a new 42-inch supply line to the city, there was just about pressure enough to force water to the top of this building and at these times the 10 pounds lost in the compound meter was a serious consideration from the point of view of that kitchen water supply. Had the department installed a 2-inch disc

meter, which was its idea of the building's true need, the loss of pressure at the rate of 1.5 cubic feet per minute would have been less than 1 pound.

At least one type of compound meter has adjustable weights on the compounding valve so that it can be made to open at any desired rate of flow. Previous to the Hartford department's appreciation of this feature it installed such a compounding valve on a 4-inch line supplying a power station. The previous meter had been subjected to very severe treatment. Within the year after the compound meter was put on this line, the disc of the small bypass meter was broken and replaced three times. After the third break the trouble was brought to the attention of the author. Investigation showed that the small meter had passed 600,000 cubic feet of water and the large 4-inch meter slightly less than this. No time was lost in finding the remedy for this and in removing some of the weight on the compounding valve.

The one point strongly brought out by the sellers of compound meters is the great reduction in the amount of water which passes the meter without being registered. Hartford as yet has not been able to get any figures on this phase of the matter. The compound meters have been principally new installations. The few meters which the department has compounded itself have been on factories and power stations where the use of water is very erratic and variable. From a study of the amount of water used before and after compounding one could not say that there was a definite increase in the amount of water accounted for by the meter. In Hartford, a yearly test of all large meters is made in place, on small flows as well as on large flows, so that they are kept in very good shape.

In selecting compound meters which the department will purchase the following points are considered:

1. Loss of pressure at various rates, low as well as high.
2. Accuracy of registration with special regard to the accuracy at the point where the flow begins to pass through the large meter.
3. Effect of entrance disturbances on the accuracy of registration.

In selecting from the several kinds which are purchased the particular meter for any installation the following points are considered:

1. Loss of pressure at rates expected on the installation.
2. Rate at which compound valve begins to open with relation to possible uses at that point.
3. Weight in connection with meter setting.
4. Space occupied if available space for setting meter is small.

PHILADELPHIA EXPERIENCE WITH COMPOUND METERS[1]

By Seth M. Van Loan[2]

To procure in a single unit a meter that will register with reasonable accuracy both high and low flows and to combine such service with minimum maintenance costs, has led some water works engineers to adopt the compound meter. A quantity consumer seldom requests a smaller connection than 2-inch and for this size and larger a meter of the compound type is catalogued.

A well recognized fact is the lack of registration on metered connections with low flows, and even with the modest consumer at his home a certain amount of water is never recorded. This is relative as the size of service increases and to place a torrent type of meter on fairly large connections and expect an adequate return for benefit rendered, is as much removed from a correct choice of measuring device as may be an installation on the same line of a meter of the purely disc type. To overwork a large disc meter is a mistake and creates bad feeling between the consumer and a water works official, for the parts will surely fail, and on the torrent type a serious loss of revenue will result from unrecorded quantities. The incentive naturally arises to produce a meter combining features which will secure, as far as may be possible, the purchaser as well as the seller.

Types of services like apartment houses, office buildings, railroad stations, department stores and many industrial plants are subject to both capacity and very low demands. During the active period of the day a large percentage of the interior fixtures is in use, which demand, compared with the flow created by the running of a few scattered fixtures in use on a Sunday or a holiday or in the extreme early hours of the day, a flexible recording device. For this class of service the compound meter is a most adaptable type and records which are tabulated below reflect the advisability of such installation.

[1] Presented at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] General Superintendent, Bureau of Water, Philadelphia.

6-inch torrent replaced by 6-inch compound meter

Readings of torrent	*cu. ft.*	*Readings of compound*	*cu. ft.*
January 11, 1917	45,558,400	January 15, 1919	zero
December 11, 1918	47,363,200	February 17, 1920	9,429,900
Difference	1,804,800	Difference	9,429,900
Average per month	75,200	Average per month	725,377

Increase per month, 650,177 cubic feet

2-inch torrent replaced by 2-inch compound meter

Readings of torrent	*cu. ft.*	*Readings of compound*	*cu. ft.*
June 19, 1917	151,800	July 19, 1918	zero
July 10, 1918	265,400	March 5, 1920	1,083,500
Difference	113,600	Difference	1,083,500
Average per month	8,738	Average per month	54,175

Increase per month, 45,437 cubic feet

2-inch torrent replaced by 2-inch compound meter

Readings of torrent	*cu. ft.*	*Readings of compound*	*cu. ft.*
March 15, 1917	511,100	January 27, 1919	zero
October 23, 1918	515,400	February 2, 1920	154,800
Difference	4,300	Difference	154,800
Average per month	240	Average per month	12,900

Increase per month, 12,660 cubic feet

4-inch torrent replaced by 4-inch compound meter

Readings of torrent	*cu. ft.*	*Readings of compound*	*cu. ft.*
November 8, 1917	6,323,800	July 17, 1919	zero
November 21, 1918	6,522,900	March 29, 1920	295,000
Difference	199,100	Difference	295,000
Average per month	16,600	Average per month	36,875

Increase per month, 20,275 cubic feet

2-inch torrent replaced by 4-inch compound meter

Readings of torrent	*cu. ft.*	*Readings of compound*	*cu. ft.*
March 9, 1917	435,500	May 17, 1919	zero
February 19, 1918	498,900	April 22, 1920	609,000
Difference	63,400	Difference	609,000
Average per month	5,763	Average per month	55,333

Increase per month of 49,570 cubic feet

3-inch torrent replaced by 3-inch compound meter

Readings of torrent	cu. ft.	*Readings of compound*	cu. ft.
March 13, 1917.....	2,965,700	April 23, 1920.....	422,400
February 27, 1918.....	2,973,700	May 11, 1920.....	467,800
Difference.....	8,000	Difference.....	45,400
Average per month.....	727	Average per month.....	45,400

Increase per month of 44,673 cubic feet

Consideration must be given to the fact that the meters replaced had become stiff and out of repair and any new meter would show increased registration.

That some favor for the compound meter has developed among water works engineers can be proved by the fact that such meters can be furnished by a number of manufacturers and in many cases the torrent type is being replaced by compound.

Referring briefly to shop inspection and tests of compound meters, it may be assumed that a $\frac{1}{16}$ inch flow registers within 2 per cent of quantity and they have under the sensitive test proved under a $\frac{1}{64}$ inch stream. The breaking point from tests on various meters has developed on a flow equal to a $\frac{3}{8}$ inch stream and full flows are well within the 2 per cent variation usually specified.

Observation has shown two types of automatic valves in construction, i.e., a horizontal cylinder in which leather cup washers attached to a spindle operate, and a varying type presents a vertical compartment in which works a brass cylindrical piston. The former may from activity in service wear down on the contact surfaces of leather and permit leakage, while the latter, if subjected to a pump pulsation on the service, may be forced from its vertical adjustment. Some irregularity of service will result should there be a long period of small flow through the connection. This trouble is caused by freezing of the automatic valve, and the flow through the service is restricted to the capacity of the small meter. Loss of water may also result through the automatic valve due to the friction between piston and cylinders. In these notes, no intention to criticize the construction details of a compound meter is intended and the principle of control on a service approaches so close to the ideal that all should be willing to offer suggestions which may eliminate any serious defects.

NEW ORLEANS EXPERIENCE WITH COMPOUND METERS[1]

By George G. Earl[2]

Experience at New Orleans clearly proves that properly constructed compound meters will, in most cases, record a much larger percentage of the flow through them than any simple meter can possibly record. Experience here also shows that time and money spent in maintaining the meters of large paying[3] consumers in a condition to record accurately the water used by these consumers are well expended The character of service which is expected by the occupants of a large building varies greatly. If flushometer valves are used, the piping must be large and consequently the meters must be large, or there will be occasions when the great volumes of water suddenly demanded cannot be delivered. If there are many baths which the occupants expect to fill rapidly, the piping must be large and the meter also, and if the piping must furnish useful fire streams on occasion, it must be still larger and have larger meters. But these heavy demands, for which large discharge capacity of piping and meters must be provided, are occasional and the average rate of flow is small. The range in the rate of flow is beyond the range of accurate registration of a simple meter, and the compound meter must be used, or the water company or department will have no record of the small flows, which make up a large total for the quarter year.

The Sewerage and Water Board of New Orleans has various types of large compound meters. It was found during the early use of these types that each had a special field where it was most satisfactory, and that no one type was wholly satisfactory for each and every class of service and location. The Board's engineers

[1] Presented at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] General Superintendent, Sewerage and Water Board, New Orleans.

[3] There are some large consumers which do not pay for water, but their supplies are metered. These large consumers need not have their supplies recorded so accurately as those of the large paying consumers, although it is desirable, of course, to have every use of water measured with fair accuracy.

accordingly designed a compound meter which has been installed exclusively during the last nine years on all connections over 2 inches in size, with most satisfactory results.

This compound meter consists of a 6-inch main valve, held closed by a small differential piston until there is a loss of pressure of about 5 per cent on the two sides of the gate, and two metered passages by-passing the main valves. When the main valve is closed, any water drawn by the consumer must pass through one of the by-passes in which there is a 1-inch meter offering a small resistance to flow. The main valve rotates on a sleeve around a hollow stem which has a solid central division forming a double Corliss valve; the metered by-passes discharge into opposite ends of this hollow stem. So long as the main valve is closed, one by-pass discharges through a large number of very narrow slots in one side of the hollow stem and sleeve to the discharge side of the main valve. When the latter begins to open, these slots are instantly closed and a triangular slot on the opposite side of the hollow stem begins to open and admit a flow, proportional to the discharge of the main valve, to pass through the second by-pass which has a meter of the same size and construction used on the first by-pass. The two meter dials are graduated to show the actual flow, so the sum of the readings of the two gives the total flow which has passed through the compound meter.

The Sewerage and Water Board is making about fifty of these meters each year for its own use. The parts are interchangeable. They can be assembled rapidly and adjusted as required for use. Such a meter can be used on any size of connection from 4 to 12 inches, inclusive, and will pass without injury any object which can go through a 6-inch opening.

One of these meters will not cause a drop of more than 5 per cent in the pressure on its inlet side until the flow is excessive for a short 6-inch connection or even for a 12-inch connection of moderate length. They have been found to operate equally well on every kind of service, including fire protection, railway standpipe and hydraulic elevator. They do as well where there is water hammer and intermittent demands for all the water the pipes will deliver as on general service with a fluctuating daily draft and only leakage to be recorded at night.

This type of compound meter records accurately any flow from a fraction of a gallon per minute to the full capacity of the pipe. It

is as accurate on decreasing as on increasing rates of flow. The "change-over point" from a flow through the by-pass to a flow through the main valve is made instantly at a low rate of flow without danger of under-recording when the shift is made.

Such a meter can be passed through a 22-inch circular manhole cover, so the work of installation or removal is simple. There are checks which prevent back-flow toward the street main or the meters on the two by-passes. There are valves which permit the removal or exchange of either of the meters on the by-passes without interrupting the supply.

At this time, with such meters on practically all large connections for paying consumers, it is believed that the only under-recording of the water supplied through such services is the flow which will not be recorded on an unusually delicate 1-inch disk meter. This is insignificant compared with any ordinary consumption, although more than can be afforded on a fire-protection connection with zero nominal consumption and nearly zero service charge.

The various types of large meters bought by the Board prior to 1911 are now mostly on the services of consumers who receive free water. These are known to under-record small flows. There is also a very large total amount of unrecorded water which passes in very small quantities through the small meters on domestic services. This feature of metering in New Orleans is now considered more important than further improvement in the measurement of the supplies of large consumers.

RECENT PROGRESS IN STANDARDIZATION OF FIRE-HOSE COUPLINGS AND FITTINGS[1]

By F. M. Griswold[2]

The specifications for standard fire-hose couplings approved by the American Water Works Association provide for a coupling of $3\frac{1}{16}$ inches outside diameter over the male end thread, with $7\frac{1}{2}$ threads to the inch, to conform to the dimensions of which it is practicable to readily convert other screw couplings to serviceable interchange with the standard when the range of diameters falls within the limits of 3 to $3\frac{3}{32}$ inches, with threads either 7, $7\frac{1}{2}$ or 8 to the inch. The process of conversion is remarkably simple and inexpensive, as has been demonstrated when such work has been done by the use of the special tools and devices perfected through the efforts of the Committee on Fire Protection and Engineering Standards of the National Board of Fire Underwriters. A detailed description of these tools is given in a pamphlet of which 14,000 copies have been distributed. In addition addresses and demonstrations have been made at conventions of State firemen's associations at Nashville, Tenn., Louisville, Ky., and Bay City, Mich., as well as at other meetings at Fargo, N. Dak., Moorhead, Minn., and Stamford, Conn. Circular letters were sent to all State Fire Marshals and Insurance Commissioners and to all Fire Chiefs in cities of over 20,000 population, with a view to arousing the widest possible coöperation in forwarding the work of standardization.

That these activities have been productive of very substantial results is evidenced by the fact that one or more sets of standardization tools have been purchased by the Underwriters Inspection Bureau or the State Fire Marshal's office having jurisdiction in Connecticut, Illinois, Indiana, Kentucky, Michigan, Minnesota, New Jersey, Pennsylvania, Tennessee and West Virginia preparatory to starting the work of standardization in their respective states, and it is gratifying to be able to record the fact that the

[1] Discussion is desired and should be sent to the Editor.

[2] General Inspector, The Home Insurance Company, New York.

work of standardization recently accomplished in Michigan by the Michigan Inspection Bureau in coöperation with a committee of the Michigan State Firemen's Association and the State Fire Marshal's office, is not only typical of the movement being initiated in several other states, but is remarkable at the same time in its demonstration of the practical results which may be accomplished through the use of these standardization tools by those not specially trained in their operation. With one set of these tools in charge of an engineer provided with an auto run-about, the first week's work in Michigan resulted in the complete standardization of all hydrant hose outlets, hose couplings and special fittings in four municipalities. It is now planned to place at least two men in that field, each in charge of two sets of tools which are to be available for continuous operation in order to assure complete standardization throughout the state within the next two years.

Since this initial effort the number of towns in Michigan which have been standardized by means of these special tools and devices was increased to 15 by September 3, 1920. The towns in which the work of standardization has been completed, together with information as to their population, diameter and pitch of thread of old couplings, number of hydrants treated and number of parts of apparatus recut, are reported in Table 1.

The work of conversion carried out in each of the towns was performed on couplings, hydrant outlets and other parts showing variations from the National Standard dimension of $3\frac{1}{16}$ inches over male thread ranging from 2.981 to 3.148 inches and covering pitch of thread of 7, $7\frac{1}{2}$ and 8 threads to the inch, in two instances both $7\frac{1}{2}$ and 8 threads being found in the respective equipments. The conditions brought into practical test every function of these conversion tools save that of reduction of thread on male ends of excess diameter, it being necessary in each instance to expand the male end, recut its thread and tap out the female member to standard dimensions, the total operations covering nearly 6,000 separate items in recutting the various parts. All of this was accomplished with such gratifying results as to encourage the hope that this demonstration may serve to convince the skeptical.

State-wide standardization has been commenced in the State of Indiana under the co-operative efforts of the State Fire Marshal and the Indiana Inspection Bureau.

TABLE 1

Michigan towns where fire hose couplings have been standardized

TOWN	POPULATION	OLD DIAMETER	PITCH	HYDRANTS	PARTS
		inches	*threads per inch*		
Berrien Springs	900	3.040 3.071	7½	32	64
Cassopolis	1,600	3.092 3.148	8	50	100
Constantine	1,500	3.014 3.064	7	47	156
Decatur	1,500	2.981 2.992	7½–8	40	218
Dowagiac	5,500	3.000	8	106	643
Lawton	1,100	3.007 3.060	7½	23	47
Marcellus	1,100	3.061 3.076	8	40	145
Mendon	1,000	3.003	8	18	110
Mount Clemens	10,000	3.003	7½–8	250	2,153
Niles	7,000	3.036 3.094	8	206	515
Paw Paw	2,000	3.072 3.082	8	40	132
Schoolcraft	800	3.000	7½	34	112
Sturgis	6,100	2.994 3.031	8	110	618
Three Rivers	7,000	3.083 3.093	8	160	540
Vicksburg	2,000	3.000	7	48	301
Totals	49,100			1,204	5,859

This brief résumé of recent progress in standardization, added to that heretofore reported, encourages the hope of its ultimate success in all sections of this country at no distant day, if all organizations interested in securing uniformity in these highly essential public utilities will more earnestly and energetically coöperate in carrying out the work. A special appeal is made, therefore, to the members of this Association to prove their faith in this standard by bringing the equipment of their several cities and towns into conformity to the National Standard, to the end that the vested interests of the community may be more surely safeguarded and the jeopardy of loss of human life by fire be thereby minimized.

THE REVENUE CHARGEABLE TO PUBLIC USES OF WATER IN THE CITY OF ROCHESTER, NEW YORK[1]

By Stephen B. Story[2]

There are two sources from which the revenue of a water works system is derived, the private takers or consumers of the water and the public treasury. The latter source has not been drawn upon very heavily in some instances for the support of the water works plant, because costs of supplying water and other services for the public have been paid from the pockets of water takers. The city of Rochester, N. Y., has been and is no exception to the group of cities whose water departments or water companies are paid nothing or, at best, inadequately for the public service they provide.

City officials, boards of aldermen, boards of estimate, and boards of contract and supply apparently have had no conception that the water or services which they demand so freely for drinking fountains, street sprinkling and cleaning, or for fire protection cost money to provide and that, unless it is paid for from the public treasury, it must be paid via the water consumers' monthly or quarterly bills.

It is necessary to distinguish carefully between the meaning of the words "the public" and the meaning of the word "consumers" in discussing questions concerning water works. The words are not synonymous. It is true that water consumers taken as a mass constitute a large proportion of the population of a community, but they are not "the public." A water taker in his relation to the water works is a private consumer and not a constituent part of the public by virtue of that fact, for all the people who make up "the public" are not water takers. When we speak of public use of water we mean use of water for purposes from which the benefit derived is not local but general. The burden of expense incurred

[1] Read before the Montreal Convention, June 24, 1920. Discussion is requested and should be sent to the Editor.

[2] Engineer, Bureau of Municipal Research, Rochester, N. Y.

in providing water for public service has, in the main, been paid by the water takers, and public officials have been consistently blind to the fact that any inequity has existed. On January 1, 1877, one year after the Rochester Water Works were placed in full operation, the Chief Engineer, J. Nelson Tubbs, communicated to the Executive Board as follows:

> That at the end of each year there be charged on the books of the Water Department against the city, such an amount as would have been collected of an individual citizen for the same uses of the water. And I suggest that the amount charged for each fire hydrant should be $50 per year; for each public drinking trough $20; for each public fountain, $15 to $50; and for each school, engine house and other public buildings, at schedule rates. In short I recommend that a regular debit and credit account be kept with the city on the books of the Department on account of the water works.
>
> This will enable those in charge to report yearly to the citizens the financial standing of the Water Works in dollars and cents, making all proper charges against them, and also giving them all proper money credits. While such a statement cannot take into account the money value of increased public health and comfort, yet it will give the water works fund a credit to which it is fully entitled, but which has no significance to the average taxpayer unless presented to him as a matter of definite amounts in currency.

In practically all subsequent reports of the Water Works, covering a period of nearly fifty years, the principle of Mr. Tubbs' remarks has received recognition, and reference has been made to the matter in many different ways. Forty years after Mr. Tubbs made his recommendation the Rochester city officials recognized the principle, for in 1917 the Department of Public Works credited the Water Bureau with $70,000 for public use of water. Last year the Fire Bureau of the Department of Public Safety credited the Water Bureau with $35,000 for "use of water." In this year's budget provision has been made for the Department of Public Instruction to credit the Bureau $14,000 for water supplied to public schools and the Department of Engineering $7,000 for water supplied to public buildings. The budget total for departmental credits to the Water Bureau is $126,000. We may believe that the principle of payment by the public for public use of water is now established in this city.

The basis for these budgetary appropriations is "guess work" pure and simple, and not very good "guess work" at that. Some of the city departments are not paying anything, some are not paying enough, and some are paying too much.

Table 1 shows the metered water used for public purposes in the city in 1919. The cost of this water has been computed at 10 cents per thousand gallons, the lowest rate of the three rate sliding scale. The total cost of this metered water is a little over $20,000.

TABLE 1

Metered city services

DEPARTMENT	BUREAU	1919		
		Consumption	Consumption	Cost at 10 cents per 1000
		cu. ft.	*gallons*	
Parks	Parks	1,047,000	7,852,500	$785.25
	Playgrounds	1,061,800	7,963,500	796.35
	Total	2,108,800	15,816,000	$1,581.60
Public safety	Fire	2,400,700	18,005,250	$1,800.53
	Police	922,700	6,920,250	692.03
	Health	282,500	2,118,750	211.88
	Total	3,605,900	27,044,250	$2,704.43
Public instruction	Schools	13,879,300	104,094,750	$10,409.48
Mt. Hope	Cemetery	1,131,200	8,484,000	$848.40
Public works	Street and Sewer	653,600	4,902,000	$490.20
	Water	327,500	2,456,350	245.64
	Market	118,400	888,000	88.80
	Garage	38,500	288,750	28.88
	Total	1,138,000	8,535,000	$853.50
Exposition Park	Aquarium	115,800	876,500	$87.65
Engineering	Municipal buildings	1,558,200	11,686,500	$1,168,65
	City total	.....	.. ..	$17,653.71
New York State	Bridges	17,200	129,000	$12.90
Monroe County	Tuberculosis Hospital	3,250,300	24,377,250	2,437.73
Grand total				$20,104.34

Table 2 is a tabulation of the quantities of water used for public purposes which are not supplied through meters. These quantities are obtained by calculations based upon the best data obtainable. The total cost of this water at the wholesale rate is $46,000. The notes give in brief form the data from which the items of Table 2 have been computed.

TABLE 2

Unmetered water for public use, City of Rochester

	PURPOSE	QUANTITY	COST AT 10 CENTS PER 1000 GALLONS
A	Street flushing (by hand)	600,000	$60
B	Street flushing (by machine)	100,000,000	10,000
C	Street sweeping (by machine)	500,000	50
D	Street sprinkling	220,000,000	22,000
E	Sewer flushing (house laterals)	3,400,000	340
F	Sewer flushing (sewer laterals)	500,000	50
G	Sewer flushing (main sewers)	100,000	10
H	Snow removal flushing	3,000,000	300
I	Drinking fountains	1,000,000	100
J	Horse troughs	110,000,000	11,000
K	Parks and playgrounds	20,000,000	2,000
L	Exposition park	1,000,000	100
		460,100,000	$46,010

A. Street flushing (by hand). Measurements of water used for hand-flushing using 2½-inch hose, 1 inch smooth nozzle, hydrant pressure average 30 pounds, are 1,000 gallons per 1,000 square yards. Figures for area flushed from Street and Sewer Bureau.

B. Street flushing (by machine). Six working days per week; 30 weeks per year. Tank capacity; flusher No. 1, 1,250 gallons; flusher No. 2, 1,500 gallons; flusher No. 3, 1,500 gallons. Flusher No. 1, 29 fillings per day; flusher No. 2, 41 fillings per day; flusher No. 3, 44 fillings per day. Two additional flushers have been purchased of same type as flusher No. 3. Four wagon flushers with 60-gallon tanks, 56 fillings each per day. Add margin for waste in filling.

C. Street sweeping (by machine). Two Austin machine sweepers, 1,200 gallons per day, 200 working days. Double quantity required for working double shift as planned. Add margin for waste in filling.

D. Street sprinkling. Six days per week; 30 weeks in season. Forty tanks filled forty times per day. Tank capacity, 750 gallons. Allow margin for wastage in filling and temporary hydrant valves.

E. Sewer flushing (house laterals). 1,600 laterals flushed per year. 15 minutes per flushing is average time water is on. Hose and nozzle at 150 gallons per minute.

F. Sewer flushing (sewer laterals). 100 sewer laterals flushed per year. 30 minutes per flushing is average time water is on. Hose and nozzle at 150 gallons per minute.

G. Sewer flushing (main sewers). 11 sewers flushed per year. 60 minutes per flushing is average time water is on. Hose and nozzle at 150 gallons per minute.

H. Snow removal flushing. Varies yearly with amount of snow fall. Estimate 30 days flushing at 100,000 gallons per day.

I. Drinking fountains. Metered flow of fountain set up in meter shop was 25 gallons per hour. Run for five months per year. 12 fountains of this type attached to fire hydrants around city.

J. Horse troughs. Metered flow of one trough at 1,500,000 gallons per year. 75 troughs operating all year in city.

K. Parks and playgrounds. Estimate based on consideration of playgrounds and parks being about half metered.

L. Exposition park. Estimate well within the actual use.

Table 3 is a tabulation of special services and uses of water which are of a public character. A discussion of the three items of this table is necessary to indicate their place in the field of public use.

TABLE 3

Special services and uses of water which are of a public character

Item 1	Rebates to charitable institutions	$15,000
Item 2	Free water supplied to industrial school	3,000
Item 3	Fire protection	180,510
	Total	$198,510

Item 1. The rebating or reduction of water bills paid by charitable institutions. Some institutions which are dependent upon charity for all or a portion of their support receive a rebate upon their water bills. The percentage of rebate is not constant but varies, certain institutions receiving larger reductions than others, governed perhaps by their degree of "charitableness." The percentages of these rebates are as follows:

	per cent
Parochial schools and hospitals	90
Y. M. C. A., orphan asylums, children's homes, Salvation Army, Rochester Athletic Club, and University of Rochester	50
Convents	25

The amount of money rebated exceeds $15,000 per year. The worthiness of the objects of any of these institutions is not questionable, and it is not within the province of this paper to say

whether or not the city should subsidize any or all of them, but it is certainly bad business to make donations to the support of institutions at the expense of the Water Bureau and under guise of a reduction in water bills. If the city is to make donations to any of these "charities" it should bill the water to the institution and collect for the same at full value. Such gifts as the city chooses to make should be made by direct appropriation.

Item 2. The water supplied by the water bureau to State Agricultural and Industrial School at Industry, N. Y. Under laws of 1910, Chapters 251 and 415, the city became a party to a transaction with the State for the removal of the school, then located at what is now Exposition Park, in the city of Rochester to a new site at Industry, N. Y. Exposition Park is a park equipped with buildings and facilities for exhibitions and expositions of various kinds. It is owned by the city but is leased to an operating association. One of the terms of this agreement was that the city would lay a cast iron pipe of a diameter greater than 8 inches from its conduits supplying Rush Reservoir to the School. The pipe to be maintained by the city, which means the Water Bureau, for as long a period as the city maintains and uses Hemlock Lake as a source of water supply. The city agreed to supply water to the School at prices charged consumers in the city and it further agreed to supply water in amounts up to 30,000,000 gallons per year without charge for a period of 25 years, dating from the completion of the pipe line.

In the nine years in which this agreement has been in force the Water Bureau has supplied a total of 229,000,000 gallons.

From a study of the gradual increase in use of water at this institution it is apparent that in 1921 the annual consumption will be in excess of 30,000,000 gallons. In each year the Water Bureau will contribute to the city's share of this agreement $3000. Its total contribution since the passage of the law has been $22,900, and the period for which it supplies free water has 16 years yet to run. At the rate of $3000 per year, this will amount to $48,000. Added to $22,900 already contributed, the total will be $70,900, the total value of water diverted to use at this institution.

It may be said that the Water Bureau received in exchange property which it now occupies for its shops and pipe yard and that free water supplied by the Bureau is its share of the payment for the property. The Bureau did receive this property, but it removed its shops and yards from other parcels of property located in sections

of the city where values were much higher. These abandoned parcels were diverted to other city uses. It is doubtful if the exchange of property occupied by the Water Bureau meant any additional outlay on the part of the city for water purposes. And if it did, the $22,500 worth of water which the Water Bureau has already contributed to the State School has amply paid the balance. The organization which conducts and operates Exposition Park received the benefit of this arrangement with the State and the charge for "free" water supplied the Industrial and Agricultural School for the next fifteen years should be paid by that organization as an "operating charge" against the park. This amount is $3000 per year.

Item 3. Fire protection afforded the city by the Rochester water works. Fire protection, as defined from the water works standpoint, is the security afforded a community by virtue of the existence of the water system and its ability to furnish a supply of water in sufficient quantities and at sufficient velocities to extinguish all anticipated fires.

It is one of the great advantages of a water supply. The fire protection which a water system makes possible cannot be measured by the amount of water used in extinguishing fires. The estimated amount of water actually used is less than an average day's consumption. It is the ability to use this water when and where it is needed that makes the protection valuable. The statement that "a dollar's worth of water at meter rates may save from destruction property worth more than the cost of the entire water system" is as true as it is trite.

It should not require much argument to show that it costs the municipal water works no inconsiderable sum to provide this service. The water supply must be such that in addition to the water ordinarily consumed there is provision for emergency drafts to the extent of one and one-half times the daily consumption. The capacity of the mains has to be such that they will convey this water, in addition to their usual provision for domestic consumption, to the point or points at which it may be needed and at such a rate as to provide water for as many as 40 fire streams at once. Special construction in the nature of hydrants, etc., is necessary to make this water available. The expense of these items is borne by the Water Bureau. The task of determining the cost of this protection is not a simple one. The custom followed by many cities in making

the determination of these charges has been to base them on averages of existing rates in nearby communities or by using the rates in cities of the same size. This method is slipshod and unscientific. This "hydrant rental," as it is usually called, has been the subject of much discussion among persons interested in rate determination. The correct and fair basis for determination of the cost of construction to provide fire protection is found by estimating the cost to provide the city with water *without* consideration for fire protection and then subtracting this sum from the actual cost. The remainder is the amount which is chargeable to fire protection. The determination of the annual charge can then be made. This annual charge should consist of two parts as:

1. A sum based upon the interest, depreciation and maintenance charges of that portion of the system that is chargeable to fire protection (this should exclude the cost of hydrants and connections).

2. A fixed sum per hydrant, consisting of interest, depreciation, repair, inspection and other maintenance charges, based on the cost of the hydrants and connections at the time of determination.

If there is no charge for fire protection, the cost of it must be collected from the water takers through the medium of water rates. The practice of supplying fire protection at the expense of the water consumers is based upon a principle which makes the use of water a measure of fire protection benefit. This principle is patently untenable. If the valuation of a man's property is an index of the value of fire protection to him, it is a measure of the benefit conferred. The quantity of water used or the use of a service connection has no relation to the measure of the benefit received. The most correct and equitable method of making the charge for fire protection is by direct taxation upon the community.

The protection afforded by two independent systems of water supply for Rochester may be discussed separately.

1. The Holly system. This system furnishes non-potable water at high pressure and is designed solely for fire protection. Its entire cost can be charged directly to this item. There are about two dozen consumers who use the Holly system for commercial purposes; their bills total about $600 per year.

The Holly system protects the congested value district and has a few ramifications outside. It affords fire protection of a special character to a special and definite district. Its protection is localized. The cost of this protection is paid by *water consumers* over

the entire city. It is difficult to imagine why a water taker living in the Twenty-third Ward should pay as much as a shopkeeper on Court Street for the protection of the Holly system. The medium of collection is unfair in that fire protection is not a just charge against a water taker and the persons from whom the collection is made are not fairly chargeable. The expense of the Holly system should be charged as a local benefit against the property owners of the Holly district and as a direct assessment.

The total expense of the Holly system is about $43,000. This is itemized as follows:

Hydrants costs for 462 hydrants at $5.50 per year per hydrant.	$2,500
Maintenance of distribution system	6,000
Operation cost Holly pumping station	24,600
Interest on original outlay	10,000
	$43,100
Less revenue from Holly service	600
	$42,500

2. Hemlock system. This system supplies water of an excellent character for domestic and commercial use in addition to providing fire protection for the entire city. The dual nature of the Hemlock supply makes the work of allocating the cost attributable to fire protection somewhat more difficult.

As indicated heretofore, the correct method of making the computation of the fire protection charge is to deduct from the cost of the works as now existent the cost of works sufficient to supply domestic and commercial consumption alone and the difference is chargeable to fire protection. To this must be added the total for hydrant expense. The above computation can be made accurately only after a careful physical survey of the entire plant with a view to determining the difference in capacities and cost, had the system been constructed without consideration for fire service.

It is conceded by water works authorities that there is a relation, more or less well defined, between the percentage of the water works construction and operating costs relating to fire protection and the population of the city served. An examination of the data upon the subject indicates considerable variance in ideas but gives some ground for the drawing of general conclusions. In small communities the entire cost of water works is usually attributable

to fire protection; there will, after the system is constructed, be a few takers. It is probable that, in communities of less than 5000, the percentage of the cost chargeable to fire protection is between 80 and 90 per cent. At the other extreme engineers have calculated that at the time when the population reaches about 375,000 the size of the system is such that the element of extra consideration due to fire needs is negligible because the capacity demanded by ordinary consumption is sufficient to fill the fire demand. Between these two extremes there may be plotted a general curve which will approximate this relation between fire provisions and the ordinary commercial and domestic consumption.

The paper presented by Metcalf, Kuichling and Hawley before the American Water Works Association at the convention of 1911 is a most able consideration of the question of determination of the correct charges for fire protection. The author has drawn upon their formulae[3] and discussion and made an application of them to the city of Rochester. If the population served by the Rochester Water Works is now 280,000, the percentage of the total cost of the system attributable to fire protection is slightly over 13 per cent. The 1920 appropriation is $900,000, and from this must be taken the hydrant expense computed as follows:

Average cost of hydrant set in place		$60.00
Interest	$2.70	
Depreciation	1.80	
Maintenance (repair, inspection, etc.)	1.00	
Total expense per hydrant	$5.50	5.50
Number of hydrants (exclusive of Holly system)		5,500
5500 hydrants at $5.50 per year each		$30,250.00

It is also necessary to deduct the Holly expense as estimated above. Thirteen per cent of the sum remaining is the charge for

[3] See "Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service," by Leonard Metcalf, Emil Kuichling and William C. Hawley, *Proc. Am. Water Works Assoc.*, 1911, page 86. The formula is

$$y = \frac{147}{x^{0.31}} - 12.1$$

in which y is the percentage of total cost chargeable to fire protection and x is the population in thousands. If the population is taken at 280,000, the formula gives $y = 13$.

fire protection afforded by the Hemlock system. Thirteen per cent of $827,000 is $107,510.

The total fire protection charge for the entire city is

Hemlock system	$107,510
Hemlock hydrant charges	30,500
Holly system	42,250
	$180,260

When this sum is compared with the $35,000 allotted to the Water Bureau from the Fire Bureau for "use of water," we see how insufficient the appropriation is.

The total of the items of public use which are mentioned in this paper is as follows:

Metered public use	$20,104
Unmetered public use	46,010
Fire protection, etc	198,510
	$264,624

The Water Bureau now receives a sum of $126,000, which is the total paid by the public for the use of water. This amount is $138,600 less than what it should be to give the Water Bureau an adequate return for the service it renders.

THE WATER SUPPLY OF THE CITY OF QUEBEC[1]

By Charles P. Casgrain[2]

The water supply of the City of Quebec is taken from the St. Charles River at Lorette, 7 miles from the city. The catchment basin of the river at this point is about 140 square miles, with a small agricultural population over which a strict sanitary supervision is exercised. The crest of the dam at Lorette is 486 feet above the main river level at Quebec, so that there is ample head for a gravity supply. At the present time the consumption is about 12,000,000 to 15,000,000 imperial gallons daily. By constructing dams on the catchment basin, so as to regulate the flow of the St. Charles River, a daily supply of 30,000,000 to 40,000,000 gallons can be obtained.

The first main from Lorette to Quebec was an 18-inch line laid in 1854. This was paralleled in 1883 by a 30-inch pipe, and six years ago by a 40-inch pipe, so that there are three independent mains to the city. These mains cross the St. Charles and Des Mères Rivers on bridges. The upper levels of the city are supplied entirely by the 40-inch main, which also furnishes water to the lower levels in case of fire.

When the works were built 75 years ago, public fountains were established at different places in the city, and the privilege of selling water at low rates from these fountains was auctioned off annually. These fountains were abandoned many years ago. Today there are about 11,000 private services in the city, and the consumption is about 125 gallons per capita daily.

A small amount of water from other sources is supplied to Montcalm and Jacques Cartier Wards.

In winter the water is perfectly clear, but after the heavy rains of spring and autumn the water contains considerable sediment. This causes very little trouble in operation. The head is so great that by

[1] Revised from an informal talk at the Montreal convention on June 22, 1920. Discussion is invited and should be sent to the Editor.

[2] Water Works Manager, Quebec, P. Q., Canada.

opening the blow-off gates and hydrants the mains are flushed clean. The sanitary quality of the supply is excellent and typhoid fever and other water-borne diseases are practically unknown in the city. On account of the small population on the catchment basin, the advantages of chlorination and filtration have been studied, but their adoption has not yet been considered necessary.

From the level of the St. Charles River to the Grande-Allée there is a rise of 366 feet. The pressure in the high-service sections of the city averages about 65 pounds and that in the lower levels about 100 pounds, which can be raised to 125 pounds by adjusting the controlling valves between the different service districts. There are about 800 hydrants and the fire protection service is so good that it is hoped the insurance underwriters will reduce their rates.

The water rates are $\frac{1}{2}$ of 1 per cent of the real value of the property served. There are several religious and charitable institutions which are charged 10 cents or 25 cents per 1000 gallons, and educational institutions are charged 60 cents per 1000 gallons. Next year it is proposed to meter the cold storage, tannery, laundry and other industrial plants using large quantities of water.

The climate of the city causes some operating conditions not experienced in many places. The winters are very cold, and the temperature drops to 30° below zero. If anything happens to the 40-inch main during such weather, there is trouble in the high service district. Last winter there were a few such interruptions of service when the thermometer was reaching 20° to 25° below zero, and during the few hours water stopped flowing in the supply main many services froze. These frozen services were thawed very rapidly, sometimes as many as a hundred in a day, by three electric outfits, with the help of the Quebec Railway, Light and Power Company, which charged $5 per service. This charge is considered reasonable.

In order to avoid the freezing of services as much as possible the city insists that every new house must have adequate provision for heating the cellar, and is very lenient in the matter of allowing water to run when the temperature is low. In fact, when there are too many complaints of frozen pipes, the consumers are advised to let the water run, for which no charge is made.

At the present time most houses have furnaces or boilers in the cellars, which prevent freezing of the services. Where there is no such heating apparatus and it has been necessary to thaw a service two or three times, the owner is told that he must attend to thawing the service himself until the cellar is heated properly.

SOME ASPECTS OF ELECTROLYSIS[1]

By Gellert Alleman[2]

Before the advent of the electric street railway, the life of iron pipes, especially those made of cast iron, seemed to be almost indeterminate. "The corroding canker and the gnawing tooth of time" apparently had little effect on those tubes, some of which had been buried in the earth for more than a hundred years. After the installation of the electric street railway, frequent breaks in pipes were experienced and the cause for these failures seemed to be shrouded in mystery. The manufacturer was suspected either of using inferior iron or employing a process which was not conducive for obtaining an efficient product; and those who laid the pipe were suspected of improper handling or installation. An examination of installed pipe sometimes revealed the fact that after the pipe had remained in the earth for a time, in apparent good condition, it suddenly began to deteriorate. Small or huge warts or concretionary deposits began to appear in spots, not regularly, on the outer surface and that which once was hard iron was later on apparently transformed to a substance easily cut by the finger nail or the blade of a knife. Frequent leaks, especially on high-pressure mains, developed. It was noticed that those pipes which were placed near electric street railway tracks seemed to be attacked by this mysterious disintegrating agent to a much greater extent than those pipes which were far removed from the electric street railway tracks, and, especially, that those pipes which were located in certain areas near the electric street railway power stations were particularly susceptible to this action. Later on it was found that an uninvited and unwelcomed guest was traveling on these sub-surface structures in order to find an easier path of return from the rail to the power station.

No possible objection would have been made to the presence of our traveler on the pipe provided it left the vehicle in the same con-

[1] Read at the Montreal Convention, June 23, 1920. Discussion is invited and should be sent to the Editor.

[2] Professor of Chemistry, Swarthmore College, Swarthmore, Pa.

dition as it found it; but, unfortunately, in leaving the pipe in its rush to reach the negative bus bar of the power station, the traveler abstracts a part of the iron of which the pipe is composed, carries it a short distance from the surface of the pipe and there leaves it. Iron which once leaves the pipe under these conditions is never returned.

All of us are, or should be, interested in the subject of electrolytic corrosion of sub-surface metallic structures. The company responsible for the escaping current not only loses the beneficial work of a valuable amount of energy, but also renders itself liable for the damage done by its stray current; the gas, water, telephone, and cable companies are particularly annoyed by the action of stray currents on their pipes and cables; the foundations of bridges, the reinforced concrete foundations of large buildings, and the iron shells of tunnels are endangered; and the public, which is dependent upon the integrity of the efficient and continuous operation of these utilities, is inconvenienced and exasperated whenever the service is interrupted or its efficiency lowered.

Some one ought to tell the truth about electrolysis. The electric railways are not anxious to do so because they are responsible for the damage caused and they see no reason why those affected should be informed or the public aroused. Their inquiry, "why awake a sleeping dog," is easily answered by the rejoinder that a dangerous thief stalks in the darkness underground and that the alarm should be given. Frequently the interests created by the joint ownership of gas, water and electric railway services, or by interlocking directorates, are responsible in some places for reticence.

Much has been written, but little told, about electrolysis. Unfortunately, and entirely too frequently, one sees in the daily press astonishing flare lines designed to excite, frighten or incense the public. The articles have been originated, in nearly every case, by so-called consulting electrical engineers whose services have been offered to, but declined by, the railways, and who seek to force their employment by the creation of public clamor. Such action is nothing less than blackmail. A number of suits entered on the recommendation of some of these self-styled consulting electrical engineers have been withdrawn after their employment or retention by the railway company. In these circumstances the water companies obtained no redress and no improvement in the existing conditions.

As the deteriorating action of an alternating current is almost negligible, provided the alternations are below 30 cycles per second, the author will confine his remarks to the effects produced by the direct current, especially on iron.

If an iron pipe and a steel rail are placed in *clean dry* sand and an electrical pressure (voltage) maintained between them, no damage takes place to either the pipe or the rail.

If an iron pipe and a steel rail are placed in *clean moist* sand, especially if the moisture holds an electrolyte like common salt, and a difference of electrical pressure is maintained between them that piece of iron which is positive will be dissolved by the current.

In the first instance no damage results because no current flows; in the latter case the iron which is positive dissolves because current is flowing, through the moist earth, from the positive iron to the negative iron. In order that a current may flow, it is necessary to have a difference of electrical pressure, moisture and an electrolyte, such as salt. Since practically all soils contain electrolytes and moisture, even if the latter is present to but a slight amount, it follows that when pipes are buried in most soils and a difference of electrical pressure exists between the soil and the pipe, or between the rail and the soil, a current will flow through the earth and enter the pipe provided the resistance of the rail or of the earth is greater than that of the pipe. It is a rule that the current, if free to travel on a number of non-metallic or metallic conductors, will follow the path of least resistance. No damage will result to the pipe as long as the current is on it, but when it leaves the pipe, through the earth, to return to the power station, it dissolves a certain amount of iron which is directly proportional to the amount of current leaving the pipe. This is equal to 0.00029 gram of iron per ampere per second (coulomb) or a little more than 20 pounds of iron if a current of one ampere flows continuously from the pipe for a period of one year. The same amount of current (one ampere flowing for one year) will dissolve or corrode about 74 pounds of lead.

It must be remembered that the current which leaves the pipe at one point may again return at another place, if the electrical conditions are favorable, and in the latter event a current of one ampere, flowing from the pipe for one year, may be responsible for the solution or corrosion of any multiple of 20 pounds of iron, or any multiple of 74 pounds of lead, the multiples depending on the number of times the current entered and left the pipe. Experience shows that this

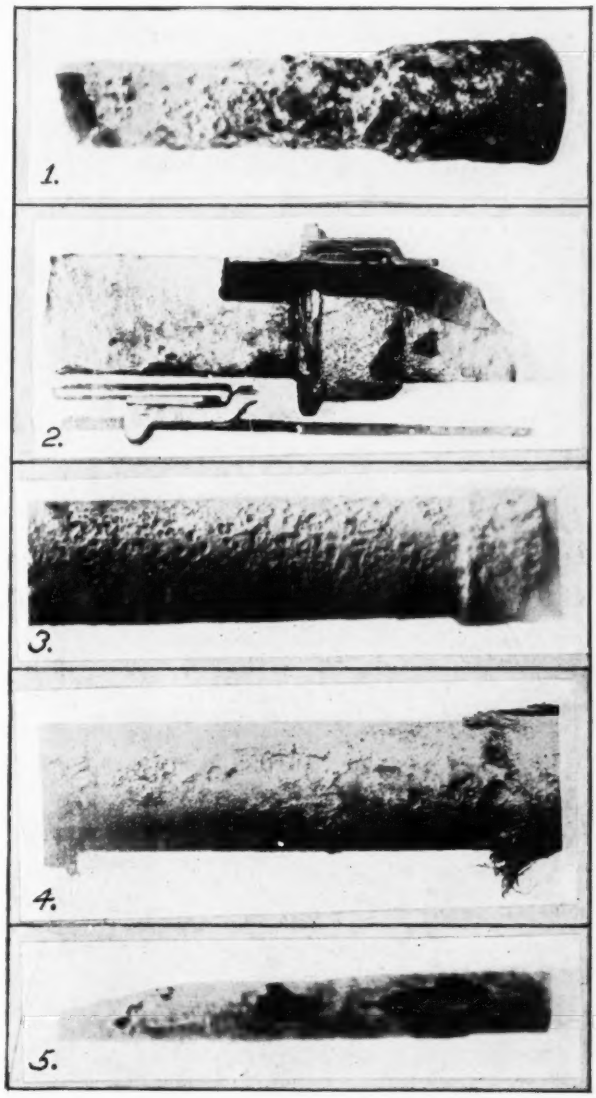


FIG. 1. CAST IRON PIPE AFTER SERVICE OF 161 YEARS

FIG. 2. CAST IRON PIPE IN SERVICE IN PHILADELPHIA 97 YEARS

FIG. 3. CHARACTERISTIC PITTINGS DUE TO ELECTROLYSIS

FIG. 4. PITTING OF PIPE ENCASED IN BURLAP SOAKED WITH ASPHALT, SHOWING THAT OUTSIDE PROTECTIVE COATINGS DO NOT PREVENT DAMAGE BY ELECTROLYSIS

FIG. 5. CHARACTERISTIC ACTION OF STRAY CURRENT ON WROUGHT IRON PIPE

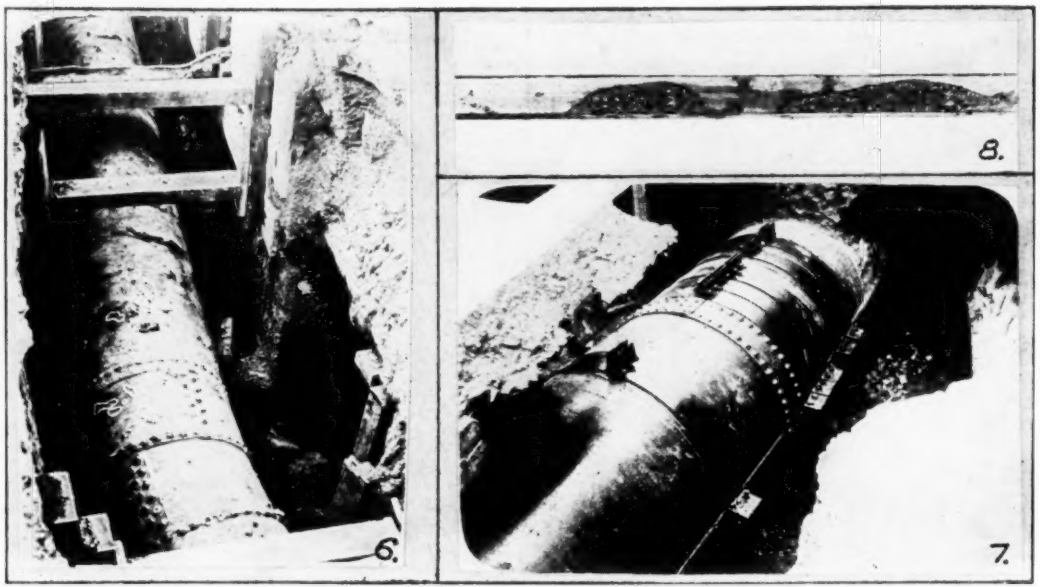


FIG. 6. DAMAGE TO STEEL MAIN BY ELECTROLYSIS, AT ST. LOUIS

FIG. 7. METHOD OF REPAIRING STEEL MAIN, DAMAGED BY ELECTROLYSIS, AT WILMINGTON, DEL.
Iron bands are placed over lead plates and firmly fixed.

FIG. 8. SECTION OF CAST IRON WATER MAIN SHOWING HOW THE IRON IS REMOVED BY THE CURRENT AND GRAPHITIC CARBON REMAINS
The darker sections indicate the carbon and the lighter sections the perfect cast iron.

multiple action certainly does take place, as the damage caused, in many cases, is actually greater than might be anticipated by the measurement of the current flowing from the pipe at any one point.

The current leaves the pipe at certain points, not uniformly distributed along an entire length of any pipe or of the whole system, because the moisture and the electrolytes in the soil at that point make better contact with the pipe and thus furnish an easier mode of exit for the current. This accounts for the "pitting" or the dissolving of one section of the pipe while another portion of that same pipe, quite near to the damaged part, is unaffected. It should be remembered that the solution of the iron first manifests itself on the outside, and proceeds, in the shape of a cone, extending towards the center, the larger area to the outer surface of the pipe, so that a section of such a damaged pipe presents somewhat the appearance of an open fan. Under the action of the current the iron first goes into solution and then reacts with the moisture present in the soil, forms a hydrate of iron which latter undergoes further change, and the final result is that there is found clinging to the outer surface of the pipe, and extending towards the negative pole, a hydrated oxide of iron. These electrolytic hydrated oxides of iron are different in physical properties and chemical composition from ordinary iron rust and an examination of the corroded specimens furnishes one of the methods by means of which electrolyzed pipe may be differentiated, with certainty, from pipe which has been damaged by ordinary corrosion.

While differences of electrical pressure between rail and pipe and between pipe and earth are not always indicative of current flow through the earth, these differences of electrical pressure, when one considers the character of most soils, furnish the ground for suspicion that the pipes may be subjected to damage.

It has frequently been stated that in order to cause damage to pipes the difference of electrical pressure between pipe and rail must be at least equal to the "decomposition voltage" of electrolytes occurring in the soil (NaCl = 4.23 volts). Such assertions are contrary to experience, and it has been clearly demonstrated that it is the solvent action produced by the current which is responsible for the damage. A slight difference of electrical pressure may be accompanied by a considerable flow of current or, on the contrary, a comparatively high difference of potential between rail and pipe may be accompanied by a much smaller flow of current.

In this connection it may be of interest to refer to a few of the results which the author obtained when attempting to determine the relative action of the current on pipes subjected to the action of various electrolytes and various electrical pressures. The electrolytes consisted of 0.05 per cent solutions of sodium chloride, potassium nitrate, and, in some cases, mixture of these two salts. The differences of electrical pressure ranged between 0.2 and 1.3 volts. The averages for 44 tests are given in Table 1.

TABLE 1

Relative action of electric currents of different voltages on metal in the presence of various electrolytes

	GRAMS IRON LOST PER COULOMB			GRAMS IRON LOST PER AMPERE HOUR			POUNDS IRON LOST PER AMPERE YEAR		
	Theory	Actual		Theory	Actual		Theory	Actual	
		In water containing electrolytes	In soil containing electrolytes		In water containing electrolytes	In soil containing electrolytes		In water containing electrolytes	In soil containing electrolytes
Cast iron anodes..	0.0002902	0.0003173	0.0003130	1.0447	1.1423	1.1268	20.17	22.06	21.77
Steel anodes..	0.0002902	0.0003434	0.0003608	1.0447	1.2362	1.2989	20.17	23.87	25.08
Wrought iron anodes..	0.0002902	0.0003404	0.0003390	1.0447	1.2254	1.2204	20.17	23.66	23.56
Piano wire anodes..	0.0002902	0.0003708		1.0447	1.3349		20.17	25.77	

44 tests: 19 cast iron; 11 steel; 12 wrought iron; 2 piano wire.

It is clear, from the results in Table 1 that the low differences of potential, during the flow of current, have as much influence as much higher differences of potential if accompanied by the same flow of current. It, therefore, appears that the recent recommendation of the representative of one of the United States Government bureaus that a difference of potential of $\frac{1}{2}$ volt between rail and pipe be permitted, was not calculated to afford protection to the pipes and that the objection made to this recommendation by the electrolysis committee of the American Gas Association was well founded.

Nowadays one hears much about the desirability of the coöperation of all concerned in an attempt to mitigate or control this serious

menace. We all heartily believe in coöperation as that word is usually understood, but of late, Americans are only too familiar with investigating committees and commissions. There are two general types of these bodies: The one is well organized, composed of men of ability and decision, who, without unnecessary delay, secure the data required, make the proper deductions and apply, with dispatch, an efficient remedy. This type of commission is responsible for the many important advances made in this field. But there is another type. Unfortunately, many of these latter are organizations masquerading under the cloak of coöperation but which are, in reality, an aggregation of skilfully picked, highly trained, technical, professional or business men who have been selected to advise these committees and whose dominating object is to balk or delay any decisive action which might be disadvantageous to the railways until a new general manager appears, or until the property, with this particular liability, passes into the hands of new owners. The technical members of this type of committee are usually honest and efficient but are merely tools in the hands of the initiated. Moreover, it too frequently happens that the men who control the appointment of these committees are advocates of some particular theory, with the result that judicial recommendations are secondary to those of policy or of expediency.

The methods of procedure of some of these joint electrolysis committees appointed for the avowed purpose of coöperating with all concerned suggest that a thievery has taken place, the culprit apprehended and that he kindly and considerately consents to confer with the rightful owner of the goods with a view of discussing who shall retain the property or who shall be responsible for the damage caused by entry.

Sometimes efficient methods of protection are proposed, but the proposals are objected to and the installation prevented, solely on the ground that the carrying out of these suggestions might result in damage to some other sub-surface structure.

Sometimes hesitation and delays result in an honest effort to decide upon the best method to pursue. Frequently, there is some justification for this fear and hesitation. Last year, a large steel water main in St. Louis was connected to the track, for electric drainage purposes, by means of a copper cable and the current on the main immediately increased from 17 amperes to 480 amperes. Had this latter current been allowed to continue to flow through the earth

to the pipe for a period of one year, it would have been responsible for dissolving, from some other pipes, 9600 pounds of iron or about 4.8 tons.

In demanding our own protection we should see that methods are employed which, if they may not benefit, certainly do not injure our neighbor. But our neighbor must not place the burden of his protection on us. Coöperation is not one sided; it involves mutual obligation and responsibility.

Iron pipes when electrically negative are not corroded by the current, but the assumption that all metals when electrically negative are immune under these conditions is incorrect. For instance, lead pipes are corroded when electrically positive and, under certain conditions, are also corroded when they are electrically negative. In the first instance the lead is dissolved by the current; and when electrically negative they may be attacked by products resulting from the action of the current. *This action accounts for the fact that the telephone interests prefer to have their lead sheaths electrically neutral. Lead water pipes should also be electrically neutral.*

Upon first consideration, it seems strange that an electrically insulating substance such as "pipe dip" should not effectively protect a pipe against electrolytic corrosion. On close examination it appears that the hydrocarbon substances constituting the "dip" are oxidized by the oxygen set free by the current and the material at that particular point is converted into a porous substance and no longer is able to insulate the pipe electrically. This action is not brought about by a "break-down" voltage but by the slow or rapid absorption of oxygen and the oxidation of the hydrocarbons constituting the dip. This action is especially rapid when the dips are made of coal tar products which contain electrolytes, unless the "tar acids" have first been completely removed.

One wonders why the stray currents from the street car tracks have been allowed to do so much damage to the iron and lead pipes of the water and gas companies and so little damage to the lead sheaths containing the telephone cables. The answer is evident. The telephone interests and the railways have been represented by able men who have accurate knowledge of matters pertaining to stray currents; the water and gas companies have too frequently been victimized by former readers of gas meters or street car motormen who have suddenly blossomed forth as consulting electrical engineers and electrolysis experts and who have been permitted to install costly and

elaborate mitigating systems many of which have been about as successful as the supposed capture of a bird by the addition of salt to its tail. The electrical interests would no more think of employing these self-styled electrolysis experts for technical advisers on electrical matters than a water board would consider the advice of the Water Witch or the Divining Rod in preference to the opinions of eminent hydraulic engineers.

Frequently we have been contented to accept the well intended reports and recommendations of committees, forgetting that it requires an executive with authority and energy to carry out these ideas. It must be remembered that the giving of a promissory note may delay, but never forestall, the payment of an obligation. Specifications alone, without provisions for their enforcement, "become as sounding brass or a tinkling cymbal," a law, non-compliance with which, exacts no penalty.

It should be insisted that the water department's specifications be carried out; and inspectors or advisers appointed and controlled by the departments, not by the railways, should see that the agreements made are fulfilled. It is far from the author's intention to suggest that any unnecessary additional burdens be placed on the shoulders of the electric railways, which are already suffering from paresis at one extremity, gout at the other, and Bright's disease in the middle. But it must be remembered that this is their Wild Indian, not the water department's, to control. Let them do so, if they will; make them, if they won't.

THE MUNICIPAL WATER SUPPLY OF MONTREAL[1]

By Thomas W. Le Sage[2]

Montreal, the commercial metropolis of Canada, has a population of about 700,000 inhabitants, making it under that heading the sixth or seventh largest center of population in North America. The city is situated on the island of that name in the St. Lawrence River and lies at the confluence of the St. Lawrence and Ottawa Rivers, whose waters meet at the upper end of the island. It is at the head of ocean navigation and to this fact its commercial supremacy is mainly due.

Founded in 1642, the city underwent many viscissitudes under French domination and its civic progresss really only dates from the beginning of the nineteenth century, and chiefly within the last 35 years, when the opening of new streets, the improvement of the highways, the erection of imposing public and private institutions have induced a large increase in population and marked prosperity to the City.

Montreal, within its administrative limits proper, comprises an area of about 28,400 acres and contains a population of 694,000. There are in Montreal two water supply systems, the municipal system supplying the main portion of the City, to the extent of about two-thirds of the above population, and a private system owned by the Montreal Water & Power Company, supplying about one-third of the population, besides two towns on the outside limits of the City.

Historical. Montreal's first attempt at water supply was made in 1801, when a company was formed to distribute water to the citizens through wooden pipes from springs in the mountain. About 1815, another company acquired the rights to supply water and establish pumping engines at the river front and put up a tank reservoir of 240,000 gallons near the citadel at a height of 97 feet

[1] Read before the Montreal Convention, June 22, 1920. Discussion is invited and should be sent to the Editor.

[2] Engineer, City Water Department, Montreal, P. Q., Canada.

above the river. In 1830 still another company acquired the rights, replaced some of the smaller piping by pipes of 10 inches diameter and replaced the steam pumping engines, in 1843, with others having a capacity of 93,000 gallons per hour.

The city became possessor of the water works through purchase in 1845, for the sum of 50,000 pounds. The city enlarged the works, constructing a reservoir of 3,000,000 gallons capacity on the Coteau Baron (now St. Louis Square), at a height of 130 feet above the river, and extended the piping system, so that by 1850, there were 19 miles of cast iron pipes and about 6 miles of lead pipes and the expenditure had been 30,000 pounds since the acquisition of the works.

In 1852, after a serious fire which destroyed part of the city had shown the inadequacy of the water supply, a report was prepared by T. C. Keefer recommending a water supply from the head of the Lachine Rapids, with an open canal 4½ miles long with sufficient fall to supply the water and hydraulic power to pump 5,000,000 imperial gallons per day to the proposed McTavish Reservoir at an elevation of 204 feet above the River. These works were carried out and put into operation in 1856. The supply had to be supplemented by steam pumps in 1868, as the city's water consumption had outgrown the 5,000,000-gallon capacity of the hydraulic pumping supply.

Meantime the project of enlarging the old aqueduct to utilize the power for pumping sufficient water to meet the city's needs, came up at various times. Finally, in 1905, estimates were prepared for widening the aqueduct to develop water power sufficient to pump 50,000,000 gallons and to build an intake out from shore and a concrete supply conduit to bring water to the steam pumps, whilst the aqueduct was being widened. The works were begun and the concrete conduit put in operation in the fall of 1909, when the aqueduct was emptied and contracts let for its widening.

In 1910, before the contractors had completed the first widening, a further change of plans was made. This contemplated a still greater increase in the dimensions of the aqueduct, to afford sufficient water power to supply and pump 100,000,000 gallons per day. This project was put under contract in 1913, but was discontinued in 1916 as unprofitable, owing to various circumstances and change of conditions, such as the breaking out of the war and the reduced cost at which purchased power for pumping could be obtained, by

reason of the great increase in water power development around Montreal since the aqueduct widening was first mooted.

These delays and interruptions in carrying to completion the aqueduct widening, will serve to explain the heteregeneous character of the main steam pumping plant at the present day. In 1909 it was surely thought that the city within three years would have its pumping done by water power to the extent of 50,000,000 gallons per day. Again, in 1911, after the changes in plans to enlarge the projected capacity from 50,000,000 to 100,000,000 gallons per day, it was again considered certain that within five years time, or by 1916, the city's pumping would be all done by water power, and the old steam plant could be left to be remodeled at leisure, to serve as reserve.

Meantime, the water consumption was increasing by leaps and bounds. In the four years 1910–1914, the daily average consumption increased from 38,670,000 to 55,750,000 gallons per day, or over 44 per cent, a greater rate of increase than it had shown in the preceding nine years. During this time steam pumps and boilers were added from year to year, as the wants required and as expediency suggested, within the restricted limits of the pumping station area.

General features of works. The city's water supply is drawn from the St. Lawrence River about a mile above the Lachine Rapids and a distance of about 5 miles from the city. The supply intake is 1200 feet from shore, the river at this point being about three-fourths of a mile wide. The water is brought down by gravity a distance of $5\frac{1}{4}$ miles to the main pumping station, through a covered concrete conduit, circular in shape with flattened invert, practically of $8\frac{1}{2}$ feet in diameter, having a capacity at the lowest stages of the river, of 80,000,000 imperial gallons per day.

At the lower end, to the south of this supply conduit, is the filtration plant, to which the water is led by gravity. Raised by low-lift pumps to the prefilters, the water flows thence to the final filter beds and the filtered water reservoir, being repumped from there to the level of the suction well feeding the main supply pumps. The filtration plant, of 50,000,000 imperial gallons capacity at present, filters only about three-fourths of the water supplied the pumps. Plans for its enlargement are under way. The whole supply is, however, sterilized by hypochlorite.

The main or low-level pumping station situated at the end of the supply conduit, near the southwestern limits of the city, has a pumping capacity of 108,000,000 imperial gallons per day, by means of eight steam pumping engines as follows:

Pumping engines Nos. 1, 2 and 4 of the horizontal reciprocating type, Worthington Duplex high duty steam pumping engines with combined daily capacity of 30,000,000 gallons.

Pumping engines Nos. 3, 5, 6 and 7 of the centrifugal type, high lift pumps, direct connected to high speed vertical triple expansion engines working at 350 revolutions per minute with combined daily capacity of 48,000,000 gallons.

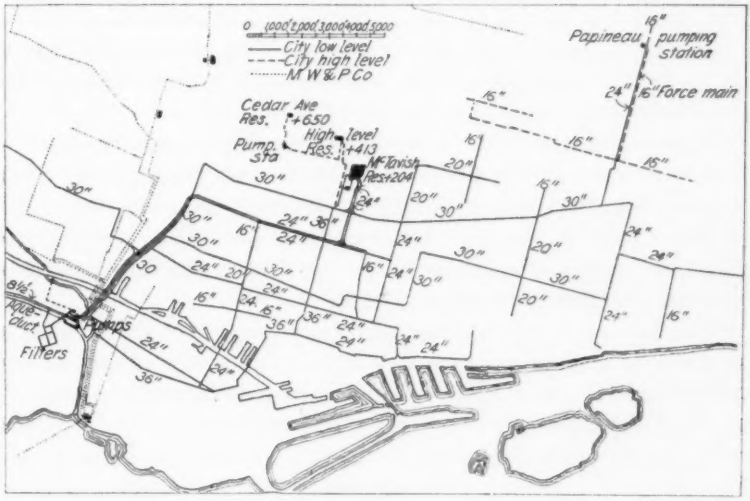


FIG. 1. MAP OF THE LARGER MAINS IN THE CENTRAL PART OF THE CITY

Pumping engine No. 8, a DeLaval centrifugal high lift pump geared to steam turbine, with daily capacity of 30,000,000 gallons.

The oldest of these pumps, Nos. 1 and 2, were installed in 1886 and 1893 respectively. They are the least efficient of the pumping plant and are to be replaced within a year by two 30,000,000 gallon electric driven high lift centrifugal pumps now contracted for. No. 4 pump installed in 1905 is of more modern type with a trial duty test of about 160,000,000 foot-pounds. The four high lift centrifugal pumps driven by direct connection to triple expansion vertical engines of enclosed type, at 350 revolutions, installed from

1909 to 1913, are representative of the change from the reciprocating to the high lift centrifugal type of water works pumping engines. Their efficiency rating on trial was from 108,000,000 to 114,000,000 foot-pounds duty. Their compactness, simplicity and freedom from the number of moving parts in the reciprocating type, as also their adaptability for working under variable loads, have shown them to be a very reliable type of water works pumping engine.

These centrifugal pumps discharge the water through the force mains against the reservoir head and into the City's distribution system. There are six pumping force mains; one of 36 inches, two of 30 inches and three of 24 inches. The 36-inch and two twenty-fours connect directly with the reservoir; the others feed into the distributing service pipes throughout the city as well as being indirectly connected with the reservoir. Thus the system may be said to be direct pumping with regulation of pressure due to the head from a reservoir of limited capacity.

The main reservoir, McTavish Reservoir, situated at the head of McTavish Street on the slopes of Mount Royal about $1\frac{1}{2}$ mile from the pumping station, has its water surface at elevation 204 above low water level of the harbor. Its capacity is 37,000,000 imperial gallons or about four-sevenths of last year's average daily consumption of 65,000,000 imperial gallons.

From the early settlements along the river front, the natural expansion of the city was towards the slopes of Mount Royal. In configuration the city is laid out in main thoroughfares paralleling the river, the cross streets rising towards the mountain in gentle grades to the level of Sherbrooke Street, beyond which begins the slope of the mountain. The elevation of Sherbrooke Street at McTavish Street is 120 feet above the river and the distance from it some 6000 feet.

The business or commercial section of the City lies principally in the lower levels of the city. The pressure head due to the McTavish reservoir supplies the system up to about elevation 130 above the harbor, furnishing water pressures of 80 pounds in the pipes of the downtown district to 35 pounds at the level of Sherbrooke Street.

High-level system. Above Sherbrooke Street and generally in that area spread out around the eastern slope of the mountain, extends the high-level system. The high-level or Peel Street reservoir situated on the Mountain slope at the head of Peel Street has

its water surface elevation at 422 feet above the harbor. Its capacity is 1,750,000 imperial gallons. The high-level system is supplied by repumping the water from the McTavish reservoir level. There are two pumping stations for this purpose; the McTavish Street and Papineau Avenue Stations. The pumping is done by high lift centrifugal electric driven pumps, with two units one of 6,000,000 and one of 5,000,000 imperial gallons in each station. The average daily consumption for 1919 of the high-level system was 11,900,000 imperial gallons.

Upper-level system. To provide for water supply to the still higher residential district of Cedar Avenue and Redpath Crescent, confined in area by the limits of Mount Royal Park, the upper-level system was installed about nine years ago. This consists of a covered reservoir of 200,000 gallons capacity, hollowed out in the Mount Royal Park at elevation 550[3] above the harbor. The water is repumped from the high-level system to this upper level by a duplicate set of electrically driven units, each of a capacity of 150,000 imperial gallons per day.

To supply the high levels of Notre Dame de Grace ward, annexed to the City in 1910, there is also provided a booster pumping station on Western Avenue to repump the water from the main low-level system. The pumping is done against the pressure head due to three tanks of 100,000 gallons capacity erected on the highest point in the ward at elevation 382 above the harbor. The daily average consumption is about 2,500,000 imperial gallons.

The town of Cartierville, annexed in 1917 and forming part now of Ahuntsic-Bordeaux ward, has its own water supply plant of 1,000,000 gallons capacity, consisting of electric driven centrifugal pumps and filtration plant; this independent supply is taken from the back river at Cartierville.

The former Town of Emard, annexed in 1910 and now part of St. Gabriel Ward, has also an independent supply, the water being taken from the city's main supply conduit and pumped, under contract, by an outside company. The average daily consumption is about 935,000 imperial gallons.

Water distribution system. The city's distribution system of piping comprises 497.6 miles of pipes from 4 inches to 36 inches as follows:

[3] The reservoir is incorrectly given an elevation of 650 ft. in Fig. 1, an error discovered too late for the map to be changed.

SIZE	MILES OF PIPE	PERCENTAGE OF TOTAL
4	54.0	10.85
6	63.0	12.66
8	203.75	40.95
10	48.62	9.77
12	79.47	15.97
16	16.0	3.21
20	3.55	0.71
24	16.6	3.34
30	9.55	1.92
36	3.06	0.62
	497.6	100.00

Of this total it will be noted that the 8-inch, 10-inch and 12-inch pipe make up about 332 miles or about two-thirds of the whole. For many years past the principle has been adopted that no pipe less than 8 inches diameter shall be laid for distribution service in the streets of the city. The mileage of 4-inch and 6-inch pipes shown in the table is mostly in outside wards annexed to the City within the past ten years. The smaller pipes in the system are generally well supported at intersecting streets by pipe of larger diameter, especially in the main portion of the City, thus providing for several effective hose streams in case of fire without the use of fire engines.

Filtration plant. In the city plant a double system of filtration is carried out, that is, the water is first passed through roughing prefilters before being passed through the regular filter sand beds.

The raw water is taken from the main supply conduit through a 9-foot circular conduit about 1200 feet from the lower end of the supply conduit and is lifted by motor-driven low lift pumps to the prefilters.

There are 16 covered prefilters, each of a net filtering area of 1200 square feet. The water passes through the prefilters at a normal rate of 115,000,000 imperial gallons per acre per day. From the prefilters the water flows by gravity to the final filters. There are 16 covered final filter beds with a total area of 6 acres. The water passes through the final filters at a normal rate of about 8,500,000 imperial gallons per acre per day and collects in the cov-

ered filtered water reservoir, which has a capacity of 6,000,000 gallons.

The filter plant, as already stated, has a normal capacity of but 50,000,000 imperial gallons per day, and as the water consumption has reached 65,000,000 to 70,000,000 gallons it is necessary to enlarge it. Plans for this work are under way, and land is available for such extension.

Quality of the water. The water drawn through the intake 1200 feet from shore at the head of the Lachine Rapids is mainly of St. Lawrence River origin. However, as the Ottawa River joins the St. Lawrence at the head of Montreal Island, its water follows the shore line inside the intake and at times the supply contains varying proportions of Ottawa water, depending on seasonal and weather conditions. The largest percentage of Ottawa water occurs in May and its presence is always indicated to the consumer by its characteristic brown color. Except in April or May, when it carries a high turbidity, this is its only objectionable feature.

The water of the St. Lawrence, from the standpoint of household use, as tapped by the intake 1200 feet from shore, is superior in every respect to that found further inshore, and the bacterial content, turbidity and color increase as the shore is approached.

The percentage of Ottawa water present in the City supply is indicated by a simple test determining the alkalinity of the mixture in parts of calcium carbonate per million.

The following tabulation of the physical and chemical characteristics of the water supplied during 1919, have been furnished by John H. Harrington, chemist of the Water Department.

Physical Characteristics, 1919

		HIGH	LOW	AVERAGE
Percentage Ottawa water		47 (May	None (Feb.)	16
Turbidity		29 (April)	7 (Feb.)	15
Color		38 (May)	6 (Feb.)	18
Bacteria per cc. 96 hours at 20°	Raw	12,900 (Dec.)	320 (Aug.)	4,600
	Chlorinated	57 (Mar.)	8 (Sep.)	19

Chemical characteristics, monthly summaries, 1919; parts per million

	HIGH (FEB.)	LOW (MAY)	AVERAGE
(1) Total solids	150.0	110.2	124.5
(2) Alkalinity (calcium carbonate)	100.0	62.0	87.0
(3) Magnesium carbonate	6.0	4.6	5.5
(4) Sulphates and chlorides of calcium and magnesium	16.0	9.5	13.7
(5) Oxygen absorbed. Organic and other oxidizable matter	3.5	9.0	5.5
(6) Chlorine (combined)	6.0	3.7	5.2
(7) Increase of total hardness due to addition of hypochlorite	1.2	0.24	0.70
(8) (7) expressed as percentage of (2)	2.0	0.24	0.80

Water consumption. The average daily consumption for 1919 was 65,046,000 imperial gallons. The estimated population served by the City's system was 449,000, giving a per capita daily consumption of 145 imperial gallons.

Figure 2 shows the average daily consumption of water for each year for the last 20 years, also the population served and the per capita daily consumption each year, also the area of the City served with water from the City system.

From 1900 to 1919 the average daily consumption has increased from 20,412,000 to 65,046,000 gallons, that is, 44,634,000 gallons or 218 per cent. In the same period, the population served has increased from 266,000 to 449,000, that is, 183,000 or 69 per cent.

From 1900 to 1910 the average rate of yearly increase of consumption was 1,822,000 gallons per day, an average of about 6.6 per cent increase each year. From 1910 to 1914 the average yearly rate of increase was 4,270,000 gallons per day, or an average increase each year of 9.6 per cent over the preceding year.

In 1914 to 1916 the rate of consumption remained stationary at about 55,500,000 gallons per day, but in 1917–1918, for two years, it rose again at a rate of increase of 4,760,000 gallons per day per year, and in 1918–1919 remained stationary at about 65,000,000 gallons for each year. The population served from 1912 to 1919 has increased 110,000, that is, from 339,000 to 449,000, or 32.6 per cent.

The consumption per capita between 1910 and 1914 jumped up from 115½ gallons in 1910 to 150 gallons in 1914 and it has been between 140 and 150 gallons practically since 1912.

It is difficult to explain this increased rate of consumption of water in the past ten years. It is no doubt partly due to more ample use of water in modern house fittings but it may also be explained by the greater use in manufacturing establishments and the greater quantities required for municipal purposes, public baths, parks and squares and the flushing of sewers and streets, all of which have greatly increased in the past ten years.

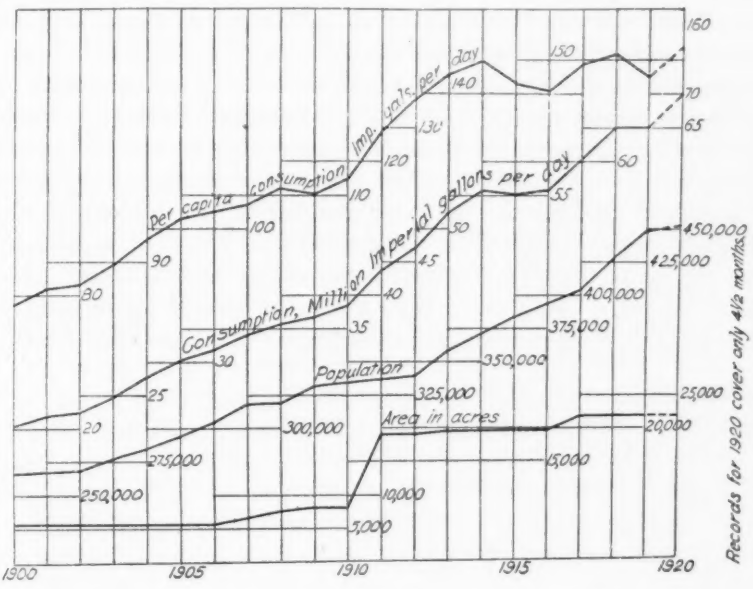


FIG. 2. CONSUMPTION DATA

Water rates and meters. The charge for water to the citizens is met by a municipal tax on all householders of 6 per cent on the assessed rental. This tax is commonly called the water rates, but it does not necessarily represent the cost of the water services. This flat rate method of charging for water is not conducive to economy from the operating point of view. The citizens have no direct inducement to economize on water and it calls for more rigid house to house inspection of fixtures, if wastage is to be controlled.

Meters are only placed in certain commercial and manufacturing establishments and other institutions where the use of water requires control against wastage. There are about 85,000 water services

and only 1668 meters in use; that is less than 2 per cent of services are metered.

The meter rate regardless of the quantity of water used is $1.15 per 1,000 cubic feet or about 18½ cents per 1000 imperial gallons. For fire protection no charge is made for water used. The proprietor may install fire protection services of 4, 6, or 8 inches on his premises for sprinkler or standpipe supply, by paying the whole cost of laying the service, and excepting in certain manufacturing establishments which are served all by meter, no charge is made for the water used for this service.

At present the city has under consideration many extensions to its water works plant. Two 30,000,000-gallon electrically driven pumps are contracted for to be delivered within a year. Plans are being prepared for enlarging the filtration plant to a capacity of 130,000,000 gallons per day. To supplement the present limited conduit supply of 80,000,000 gallons, the aqueduct is to be prepared for service to convey additional water and also furnish power in a modified form. Additional reservoir capacity and an increase in the number of force mains are also projected in the near future.

SOME FEATURES OF THE WORKS OF THE MONTREAL WATER AND POWER COMPANY[1]

By F. H. Pitcher[2]

The Montreal Water and Power Company was organized in 1891 for the purpose of furnishing a water supply to the outlying municipalities of the City of Montreal and developing electric power. These municipalities were disposed in a ring around the city proper and extended from the St. Lawrence River at a point west of the City going north and east to a point on the river east of the City. A line drawn through their center forms an approximate semi-circle having a length of 10 miles, as shown in figure 1. The total area of this territory is approximately 17.5 square miles.

These municipalities, as they were then called, were independent communities having their own municipal Council, borrowing power etc., like any other village or town. Most of them had, at that time, no public water supply of their own. They took water for the supply of their small distribution systems from the City of Montreal by large meters. The City of Ste. Cunegonde on the west was an exception. This municipality had its own pumping plant and furnished water to the Town of St. Henry by large meters. All the rest were receiving their supply through large meters from the City of Montreal.

The rates for water so furnished were high, 40 cents to 75 cents per 1000 imperial gallons being charged by the city, the supply was unsatisfactory and the scheme not sufficiently comprehensive to allow normal development of vacant property within the municipalities. The company, then, by undertaking the responsibility of the supply at reduced rates and extensive pipe laying ahead of immediate requirements, was enabled to obtain long term franchises from practically all of them and amalgamate them into a unit water

[1] Read before the Montreal Convention, June 22, 1920. Discussion is invited and should be sent to the Editor.

[2] General Manager and Chief Engineer, Montreal Water and Power Company.

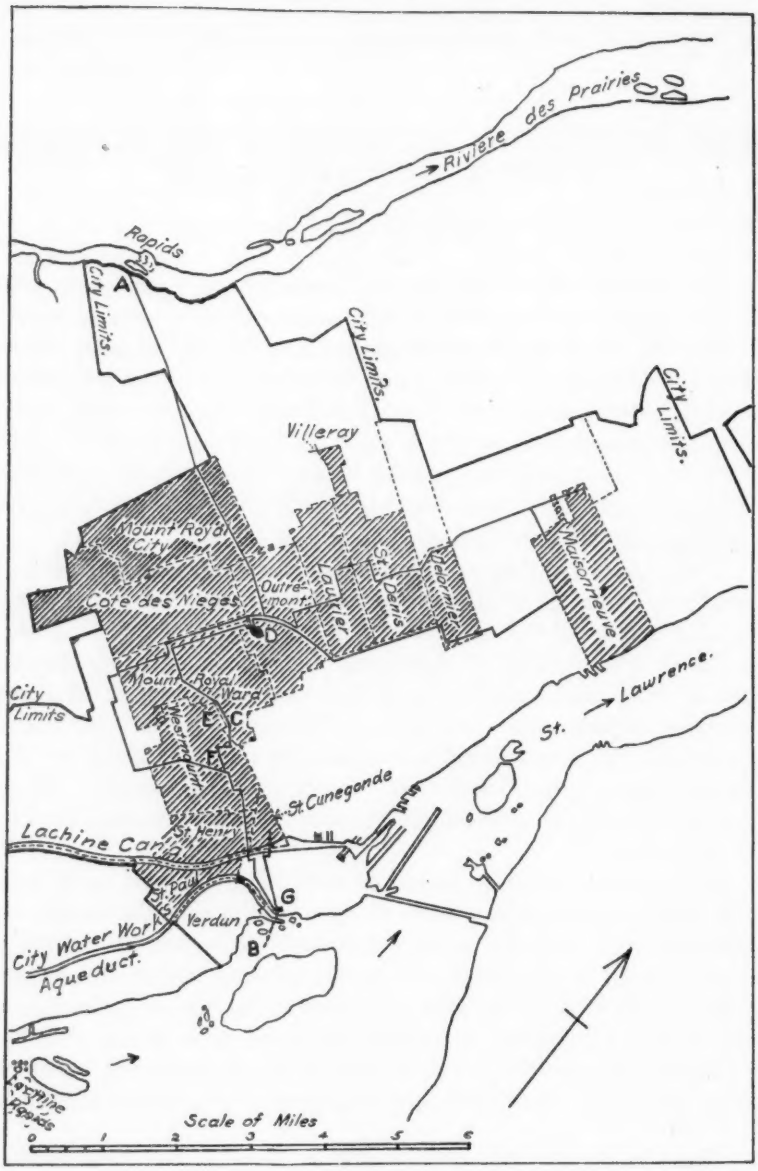


FIG. 1. DISTRICTS SERVED BY THE MONTREAL WATER AND POWER COMPANY

works system. It is believed that this enterprise more than any other has been responsible for the extraordinarily rapid growth of the outlying municipalities of Montreal.

Starting from the west and going north and east around the semicircle, these municipalities were then called the Town of Verdun: the Town of Cote St. Paul: the City of Ste. Cunegonde: the Town of St. Henry: the Village of Turcot: the Town of Cote St. Antoine: the Town of Notre Dame des Neiges: the Town of Cote des Neiges: the Village of Outremont: the Village of St. Louis du Mile End: the Village of Villeray: the Town of Cote St. Louis: the Town of Delormier: and the Town of Maisonneuve. These fourteen municipalities had, at that time, a total population of 30,000 approximately.

Since then, all, with the exception of the Town of Verdun, the Town of Cote St. Antoine, and the Village of Outremont, now respectively the Cities of Verdun, Westmount and Outremont, have been annexed to the city and form various wards and parts of wards of that corporation. Their aggregate population is today over 300,000 and approximate mileage owned by this company is 190.

The company still supplies all of the above with the exception of Verdun and Delormier, which were on a wholesale meter basis, where the contracts have expired, and Turcot Village, which is now a part of Notre Dame de Grace Ward. With the exception of Villeray and the Town of Cote des Neiges, all are supplied under a franchise system; the company owning the pipes and entire water plant and collecting the water rates. The two exceptions are supplied wholesale by meter connections to their own distribution systems. Recently the company has obtained a contract for the supply of the new Town of Mount Royal or Model City. This is also wholesale and on a meter basis, the town owning and administering its own distribution system.

The original idea was to supply all this territory from what is called Back River at point *A* on figure 1. The company had obtained a water power site there and the pumping was to have been done by hydraulic power. Electric power development was also contemplated. For various reasons this scheme was abandoned and the point of supply fixed at the present location on the St. Lawrence River near the head of Nuns' Island, at the point *B* on the plan.

An unusual feature of the system of the company is the extreme variation in elevation of the territory to be supplied. About 10 per cent of the territory is at an elevation of 30 to 40 feet, City datum, called the low level (St. Paul, St. Henry and Ste. Cunegonde); 25 per cent in the slopes of the mountain (Westmount, Cote des Neiges and Outremont high levels), called the high level; the remaining 65 per cent at an elevation of 150 to 225 feet, city datum, called the intermediate level. This latter level also includes Maisonneuve, part of which lies below 50 feet elevation but owing to its location is supplied through the intermediate system.

Included in the high-level territory is a small but rapidly growing community situated near the top of the Westmount Mountain, which is supplied by a third pumping plant delivering water at an elevation of about 600 feet and called the Mountain System. As will be seen, the levels vary between that of the river to about 600 feet above the same. By far the greater proportion is at the intermediate elevation.

Reservoirs have been built at 470 feet elevation on Cote des Neiges Road at *C* on figure 1 and at 360 feet elevation in Outremont at *D* figure 1, also shown in figure 2. The former has a capacity of 7,500,000 imperial gallons and the latter 45,000,000 gallons. There is a small tank of 60,000 gallons on the top of the Westmount Mountain at a point *E* on the plan, regulating the supply of the Mountain System.

The water is pumped from the clear water basin of the filter plant at the Main Station, *G*, figure 1, foot of Charlevoix Street, by two systems of pumps working at different pressures. For the low level there are 7,500,000 gallons electric turbine pumps in duplicate operating at 100 pounds pressure pumping direct without a reservoir. Automatic valves, connected with the Outremont Reservoir, are provided for emergencies.

For the intermediate, high and Mountain System supplies, there are in all at this station five electric turbine pumps having a combined capacity of 54,000,000 gallons and operating at 200 pounds per square inch. In addition, there is a steam reserve plant, consisting of boilers, etc., and steam turbine pump having a capacity of 15,000,000 gallons per 24 hours for this service.

On Clarke Avenue, Westmount, at the point *F* on the plan and at an elevation of 200 feet, city datum, there is a booster station taking water by a connection from the steel main at a pressure of

80 pounds and raising it to the reservoir in Cote des Neiges Road to an elevation of 470 feet. This station is equipped with two electric turbine pumps of 6,000,000 gallons capacity each and a small reserve steam installation.

At the Cote des Neiges Reservoir, at point *C* on the plan, there is a small pumping station having three electric turbine pumps and one gasoline reserve turbine pump, the combined capacity of which is 2,000,000 gallons. This station takes water from the reservoir and raises it to 610 feet elevation for the Mountain System.

The distribution systems at the various levels are connected to the different rising mains. At certain points it has been found necessary to introduce reducing valves rather than further to subdivide the pumping levels.

Main pumping station. This is located on the original site of the old Ste. Cunegonde water works at point *G* on the plan, which the Company acquired in 1891. It then consisted of an old steam pumping plant intake and a 12-inch force main about one mile long, running through Ste. Gabriel Ward of the city, crossing the Lachine Canal and supplying the former City of Ste. Cunegonde. This corporation also furnished the water supply of the adjoining City of St. Henry.

The first electric pumping installation of the Montreal Water & Power Company was made in 1898 at the site of this old pumping station and consisted of an electrically driven reciprocating pump of 5,500,000 gallons capacity. This was driven by a synchronous electric motor of 400 horse power through spur gears. Later in 1903 another similar unit of about the same capacity was installed. These pumps becoming obsolete have been abandoned and disposed of.

At the same time the force main capacity to the upper and lower levels was increased by adding 24-inch and 16-inch cast iron mains.

About this time the intermediate territory commenced to fill up, the distribution systems having been proceeded with from 1898.

More pumping and force main capacity becoming immediately necessary, a 15,000,000 gallon electric turbine pump was added and a 36-inch steel main 7½ miles long running around the Mountain to the Outremont Reservoir site was constructed, and there connected to the intermediate distribution system in Outremont and territory to the northeast. Pending the construction of the Outremont Reservoir, it became necessary to add a 15,000,000-gallon steam

reserve. This consisted of a 1500-horse power steam turbine driving a single-stage turbine pump to operate at a maximum of 200 pounds pressure. Water-tube boilers, boiler house, chimney, and all accessories were installed and ready for operation in 1908.

A new 5-foot steel intake, taking water higher up and further out in the river had been installed just prior to the installation of the reserve steam plant.

Later three 10,000,000-gallon electric turbine units and one 7,000,000-gallon unit were added. In all, there are today on the intermediate service, turbine pumps having a combined capacity of 69,000,000 gallons per 24 hours, including the steam reserve.

The old geared pumps working on the low level, proving uneconomical on account of cost of repairs, have been superseded by the 7,500,000 gallon electric turbine pumps above mentioned.

Before the installation of the filter plant, the suction of the plant was 10 to 20 feet and it was found impossible to keep the impellers in the turbine pumps. Many different designs and various materials were tried but rapid pitting and hence destruction of the impellers invariably occurred. After the filter plant was put into operation and with the consequent decrease in the suction lift, this trouble disappeared. The low lift turbine pumps in the main station, which take water from the river, have been set at a low level in order to obviate this difficulty.

Each turbine pump has been provided with a separate Venturi meter. The cost per water horse power at the mains, including all pumping charges, maintenance of buildings, engineering and other overhead costs, but not interest or depreciation, is $60.60 per annum.

Filter plant. In 1909 and 1910, the company made the necessary arrangements with certain municipalities for the supply of filtered water and in 1912 the present filter plant was put into operation. This is of the well-known type of rectangular concrete construction operating at the rate of about 125,000,000 imperial gallons per acre per day. It has the usual negative head control, hydraulic operating tables, etc.

The coagulation period is one hour. This might have been longer, as in the Spring and Fall difficult water of high color and low alkalinity is treated. However, the characteristics of the effluent have always been maintained at a satisfactory limit.

Originally this plant was provided with the usual hypochlorite plant for final sterilization but during the war an electrolytic chlo-

rine plant[3] was installed which proves much more satisfactory both in cost of operation and quality of effluent.

Chlorine gas, including all charges, is produced at less than 9 cents per pound and the installation has paid for itself twice over.

Just previous to the installation of the chlorine gas plant an alum plant[4] was added, the war interfering to such an extent in the price and the supply of alum that it became necessary to make it at the plant.

Bauxite and sulphuric acid in the requisite proportions are mixed and allowed to solidify in a concrete tray. The resulting crude alum is used exactly as was the refined product obtained before. This costs the Company $30.00 per ton today, all charges paid, and has resulted in a very considerable saving. Its manufacture, is, however, a horribly messy job. It would be desirable to provide special and separate buildings for it.

The present capacity of the filter plant is about 25,000,000 imperial gallons in 24 hours. Provision has been made in its design for doubling its capacity. When the enlargement is undertaken it is the intention to correct the matter of the coagulation period and to make other minor improvements.

Clarke Avenue Station. At one time prior to the installation of the main around the Mountain and the building of the Outremont Reservoir, this station handled all the water for the high, intermediate and Mountain System levels. The overflow from the low level entered a catch basin at this point, from which the pumps took their suction and delivered the surplus into the Cote des Neiges Reservoir.

At this time the station was equipped with about 12,000,000 gallons capacity in electric turbine units and about 10,000,000 steam reserve.

Today it handles only the water for the high levels and the mountain system and does this with 6,000,000-gallon electric turbine pumps in duplicate and a 3,000,000-gallon steam reserve.

Mountain System Station. The plant has been gradually increased to meet the demand and with the small storage capacity provided on the Westmount Mountain, economical operation has so far been realized.

[3] See JOURNAL, September, 1917, page 337.

[4] A paper by James O. Meadows on this plant was read at the Montreal Convention and is printed in this number of the Journal.

Motive power. Under normal conditions all pumping is done by electric power purchased under contract from an outside supply company. The price of power, conditions of service, together with the force main and reservoir capacity provided, have given fairly satisfactory operating conditions up to the present time.

Difficulties of operation. The extremes of temperature met with are the source of special difficulties in the operation of water works in this locality. All main pipes and services installed by the Company are laid with a minimum cover of 5½ feet, which is sufficient to protect them from frost under conditions ordinarily met with. There have been, however, two exceptionally severe winters recently, 1917–18 and 1919–20, the intervening winter 1918–19 having been on the other hand exceptionally mild.

In both of the former years, long continued cold weather occurred before any protection from snow fall was obtained. The result of this was that the frost penetrated much deeper than usual, and in localities where the pipes were laid in gravel or rock-filled cuts, the frost reached a point 7 feet below the surface, and in one extreme case was found during last winter over 8 feet deep. The trouble was noted especially where pipes or hydrants were situated near sewer manholes or gullies. These, being without the protection of snow, permitted the frost to reach points which had not been affected in previous years.

The growing practice of clearing snow off the streets and sidewalks is also responsible for increasing trouble from frost. This constitutes a serious menace, for even in the construction of new services, it is useless to provide greater depth of cover when the connection to the main must be made at the old depth. The chief trouble from frozen pipes, however, occurs on the branches between the street line and the building served. This part of the pipe is laid by proprietors and is not under the control of the company. These services are frequently placed under walks which are kept cleared of snow and in many cases pass below depressed entrances to basements, leaving them with from 1 to 3 feet cover.

The enhanced cost of calling in a plumber today has led the consumer to rely more and more on the company for thawing out such services. This is done by means of electric current, passed through the pipe long enough to heat it and free it from frost. Current was formerly obtained for this purpose from the local power company by means of transformers connected to the 2200-volt mains and delivering about 400 amperes at about 50 volts.

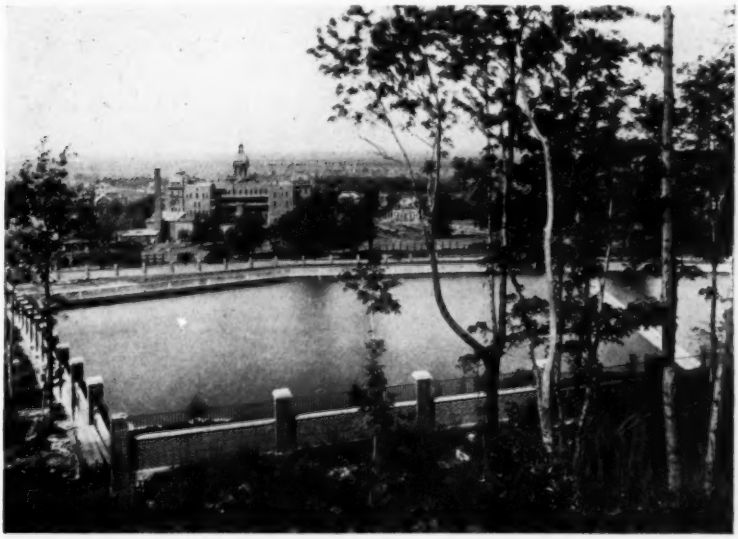


FIG. 2. THE OUTREMONT RESERVOIR

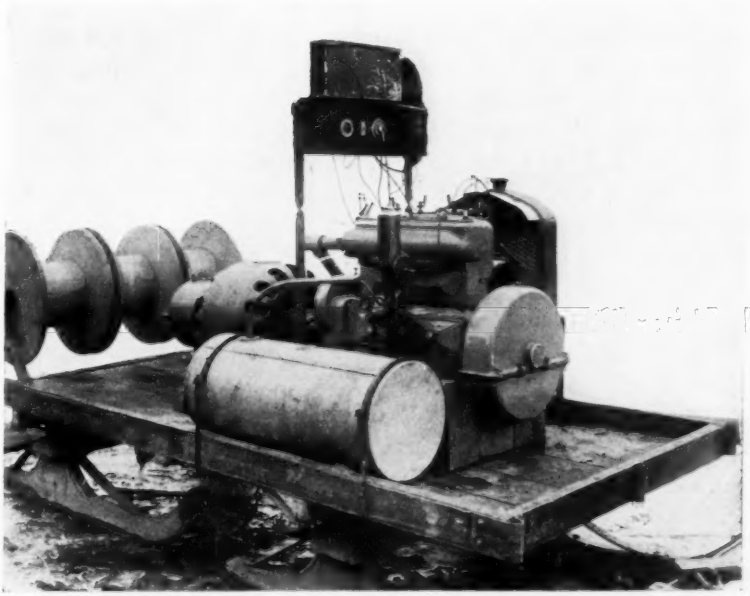


FIG. 3. GASOLINE-DRIVEN THAWING OUTFIT

Last winter two self-contained generating units, figure 3, were built, consisting of gasoline motors and specially designed generators, which have proved successful and much more convenient and rapid in actual service than the former outfits, as well as considerably less expensive.

The following figures for the past ten years show the extent and variation of the frost troubles in the distribution system.

YEAR	TOTAL NUMBER OF SERVICES	NUMBER OF SERVICES FROZEN	TOTAL NUMBER OF HYDRANTS	NUMBER OF HYDRANTS FROZEN
1910–11	37,705	470		
1911–12	41,620	2,313		
1912–13	45,680	544		
1913–14	48,926	901	1,286	
1914–15	51,584	83	1,341	477
1915–16	52,242	476	1,367	850
1916–17	52,690	485	1,388	589
1917–18	52,960	2,686	1,402	1,528
1918–19	53,122	18	1,405	224
1919–20	53,532	2,671	1,406	955

In addition to the frost trouble in distribution system, there is occasionally some trouble with frazil ice at the intake. By constant vigilance, however, in preventing the accumulation of ice at the mouth of the intake, no serious trouble has been encountered for many years.

Method of fixing water rates. With only two unimportant exceptions, the company collects the water rates from the consumers throughout the territory it supplies. The annual rates are determined by the rental value of the properties supplied, as appears by the municipal valuation in force. Manufacturers and a few other classes of consumers have, under certain conditions, the right of supply by meter. In some districts provision has been made for a hydrant rental and throughout the system a small charge of 5 cents per sprinkler head for private fire protection is levied.

In 1891, when the franchises were obtained and the rates were fixed, the City of Montreal had water rates which were considered, principally by the newspapers, as high. The company gave considerable discounts on those rates and adopted the same basis. These discounts varied from 25 to 60 per cent, and were accepted for 25 years subject to a revision downwards at the end of that time.

During the past 25 years, the city rates have been made a sport of the municipal politicians and until lately were very much below the cost of the service. Recently, however, the ordinary city rates have been advanced 50 per cent and some special rates in a greater proportion. But even today the water rates of the city do not cover the cost. As against this condition, the Company has not been in a position to obtain an equitable adjustment of its rates, the principal obstacle being, of course, in the nature of its contracts. Naturally at the present rates, with expansion in building at a practical standstill and with ever increasing cost of labor and material, the going is hard.

Increasing rental valuations will, if realized in the valuation rolls, help matters somewhat.

The meter principle for private houses has never found much favor in this part of Canada. One of the difficulties would be the necessary winter waste to prevent freezing of private services from the street line to the houses, over which the company has no control.

The system best calculated to meet present day conditions for water works plants is undoubtedly cost plus a fixed return on capital.

WHAT IS THE LEGITIMATE USE OF WATER?[1]

By Caleb Mills Saville[2]

In its broad and general sense the question, "What is the legitimate use of water?" opens up such a large opportunity for discussion that it seems impracticable at this time to attempt to do more than consider a few special problems.

For example, is it a legitimate purpose to use pure water brought at great expense from long distances for the extinguishment of fires, or is it in keeping with modern thought in conservation to draw from the city supply large quantities of filtered water for use in mechanic arts when other water will suffice? Related to this phase is the moot question as to the propriety and desirability of selling water to a large consumer at or below cost in order to obtain his trade. These, perhaps, may be called questions of ethics, but every gallon of water so used hastens the time when an additional supply is needed, and with every increase in supply progressively greater difficulty in obtaining proper water for domestic use must be encountered. This results from the growing scarcity of good water supply grounds in the vicinity of our cities and the mounting cost of construction works for extension and for water purification.

Among the many phases of this problem is the quantity of water to be judged as legitimately used or useful for that purpose which must in the end take priority over all others; namely, the use of water for human needs and for potable purposes.

A statement of this portion of the problem resolves itself most naturally into a presentation of statistics and results of inquiry. This in turn can only be discussed in a very general way without study of data, some of which it is the author's purpose to present in the hope that deductions may be drawn or ideas suggested which may be of value for the improvement of water works operation.

[1] Presented at the Montreal Convention, June 23, 1920. Discussion is invited and should be sent to the Editor.

[2] Manager and Chief Engineer, Water Department, Hartford, Conn.

The primary object is to serve the people with a necessary commodity in as economical and efficient a manner as possible.

In studying the data collected and the conditions under which they were obtained, it is evident that *rate* of use is nearly as important as the actual consumption of water; that these two are interrelated, and that present day living conditions and requirements must be considered.

There are causes for increase in consumption other than waste, and a bare comparison of per capita consumption figures may be most misleading.

The basis on which the number of consumers is estimated, the character of the houses, the requirements of the inhabitants in installation of modern plumbing facilities, the extension of sewers and other growing demands for modern personal conveniences, have much to do with the legitimate use of water. The pressure under which water is supplied, the increase in pressure in the same system due to additions and reconstruction, and the requirements for mechanic arts and commercial purposes are of no small effect. All of them must be given weight when comparisons are made of unit consumption records.

As recently as 15 years ago many tenement houses in our largest cities were unsupplied with plumbing fixtures other than a cold water faucet and a community water-flushed toilet. Today few apartment blocks of even low rent value in our cities are not fully equipped with individual conveniences which promote a comparatively lavish use of water, and public health authorities are actively pushing these requirements.

These tendencies of the times must be recognized by the water works man and provision made for future water service in all communities to meet the present demands of city dwellers.

This probably means a greatly increased per capita domestic demand during a transition period of a score of years perhaps in suburban and country localities and thereafter in all localities a more slowly advancing rate of increase which would tend to approach a uniform rate of consumption.

For this transitition period it seems probable that the rate of increase per capita per year may be at least from 2 to 3 gallons more than the present normal and thereafter provision should be provided for an annual increase of from $\frac{1}{2}$ to $\frac{3}{4}$ gallon per day per consumer.

The first and most practical method for successfully coping with this legitimate increase in the use of water is, of course, the elimination of needless and useless waste. Methods for accomplishing this result, admirable in itself, however, should be carefully considered with reference to cost and the results practicable of accomplishment in individual cases. While it is always commendable to stop waste of any kind, the immediate financial results of saving the last drop of water are not so apparent in connection with an unfiltered gravity supply from an abundant source as they are when all the water must be pumped or filtered, or both.

The city of Hartford, Conn., is practically fully metered, the only unmetered supplies being fire protection services unused except in emergencies and some use of water for street watering, sewer flushing, water main flushing and by fire hydrants. In 1915 a rather intensive study was made of water use conditions with the following results:

	MILLION GALLONS PER DAY	GALLONS PER CAPITA	PER CENT OF TOTAL
Domestic	4.74	33	50.4
Manufacturing	2.73	19	29.0
Public	0.43	3	4.6
Unaccounted for	1.50	10.5	16.0
Totals	9.40	65.5	100.0

In 1919 the average daily draft has increased to 11,880,000 gallons per day, and while as yet no close study has been made, it seems likely that although the unaccounted-for water may have somewhat increased, it is still less than 15 gallons per capita per day or perhaps 20 per cent of the total consumption of the city.

Manufacturing and industrial. The amount of water used from the public supply for manufacturing and industrial purposes in Hartford is quite inconsiderable considering the numerous and extensive plants which are located here. This condition is accounted for by the fact that much of the water used for these purposes is furnished by private supply from driven wells or nearby streams. This condition, too, somewhat accounts for Hartford's comparatively low consumption and undoubtedly, if as much water were drawn here from the public supply as in some other cities with similar industrial activity, the rate of per capita consumption would be considerably increased from perfectly legitimate uses.

Public. A study of the principal uses of water for public purposes indicates that the amount of water so used probably does not exceed 450,000 or 500,000 gallons per day, allocated about as given below:

SERVICE	MILLION GALLONS PER YEAR	GALLONS PER CAPITA PER DAY
Fire—Station use	3.7	0.070
Extinguishing fires	3.3	0.063
Parks	11.7	0.223
Police station use	0.9	0.017
Streets—Drinking fountains	0.4	0.007
Horse fountains	2.3	0.042
Sprinkling and flushing	34.1	0.648
Miscellaneous	0.4	0.007
Schools	24.7	0.473
Miscellaneous buildings	20.8	0.397
Estimated unaccounted for	55.2	1.053
Totals	157.5	3.000

The total use of water for extinguishing fires is comparatively small in the course of a year. The rate of demand, however, for short periods is often very great, so great, in fact, that in cities of 100,000 to 150,000 population a reasonable requirement for fire protection service often equals or exceeds the maximum hourly rate of draft of an ordinary day. The total amount of water used by the Fire Department of Hartford in the past year was about 7,000,000 gallons, or a little over a pint per capita per day, of which about one-half was used in the maintenance of 16 stations, including washing of hose and apparatus. The remainder was used in extinguishing fires.

The following data from Fire Department records of 1914 is an indication of service conditions in this city:

Total actual fire alarms	628
Number fire calls at which water was used	105
Number of times pump service available	63
Number of hose streams in use, average	2
Length of hose line, average, feet	380
Usual size nozzle, inches diameter	1 to 1¼
Average hydrant pressure in service, pounds	60 to 80
Average pump pressure, pounds	100 to 200
Total amount of water used, gallons	3,000,000

Value of property included in the fires	$7,973,109
Insurance thereon	3,348,310
Insurance loss	14,590

The following table shows the duration of hose service at fires in 1914:

NUMBER OF FIRES	DURATION OF SERVICE
50	15 minutes
25	15 minutes to 30 minutes
15	30 minutes to 1 hour
11	1 hour to 2½ hours
2	2½ hours to 4 hours
2	4 hours to 6 hours

Of the 105 alarms at which water was used, three or more streams were in service at only 16. There were seven calls at which five or more streams were used, four at which nine or more were used, and one at which thirteen streams were in service.

An analysis of the seven calls at which five or more streams were in service is given in table 1.

TABLE 1

Analysis of the seven calls where five or more streams were in service

DATE 1914	NUMBER STREAMS		LENGTH OF TIME IN SERVICE						DISCHARGE OF STREAM GALLONS PER MINUTE			MAXIMUM RATE OF DISCHARGE				EQUIVALENT NUMBER 250 GALLONS PER MINUTE STREAMS	ESTIMATED TOTAL AMOUNT USED, GALLONS
	2½ in.	3 in.	Aver. h.	Aver. m.	Min. h.	Min. m.	Max. h.	Max. m.	Aver.	Min.	Max.	h.	m.	g. p. m.	m. g. m.		
Jan. 20	9	—	4	20	3	—	6	—	260	240	285	3	—	2,360	5.40	9.5	613,370
Feb. 21	11	2	2	35	2	—	4	30	365	175	645	2	—	4,765	6.86	19.1	648,380
Feb. 26	8	2	2	20	1	—	4	15	315	260	425	1	—	3,130	4.50	12.5	426,530
May 23	5	—	—	30	—	10	1	25	225	200	270	—	10	1,120	1.61	4.5	35,770
Dec. 4	3	2	1	25	—	35	4	—	335	260	450	—	35	1,665	2.40	6.7	151,220
Dec. 4	7	2	1	25	—	35	2	10	325	245	565	—	35	2,930	4.22	11.7	239,670
Dec. 18	5	—	—	55	—	15	1	30	270	210	300	—	15	1,340	1.93	9.3	67,250

These seven fires used a total of 2,182,190 gallons, or about two-thirds of the entire amount used to put out fires, leaving 1,117,810 gallons to be used by the other 98 calls, or an average of about 11,400 gallons per fire call.

On January 29–30, 1917, occurred the most serious fire that has yet visited Hartford. On that date a large department store was destroyed with loss aggregating $613,000. Twenty pieces of apparatus were in action, including 13 pumping engines and a water-tower. In all the equivalent of 38 single streams were employed simultaneously at this fire. It is estimated that about 3,500,000 gallons of water were used at this time, and for four consecutive hours the draft was at a rate of 10,000 gallons per minute. This rate, it is interesting to note, is exactly that recommended for Hartford's Congested District by the engineers of the National Board of Fire Underwriters in 1916.

· *Unaccounted for water.* This amount of water is the difference between the amount registered on the master meter on the supply pipe line and the sum of consumer meters, plus a comparatively small amount to known unmetered uses.

The quantity thus drawn is due to leakage from underground main pipes and services, under-registration of meters, probably some illegitimate use and some unmetered public use, as for flushing water mains, factory tests of private fire protection systems, etc.

The total amount unaccounted for is estimated as less than 15 gallons per capita per day. In his report on the Boston Metropolitan Water District, the late Dexter Brackett, one of the foremost water distribution engineers of the country, stated this amount to be "a minimum quantity and could only be maintained by a thorough meter system and constant inspection." John R. Freeman, in his report on New York's Water Supply (1900), puts 10 gallons per inhabitant per day as "the irreducible waste with every service pipe metered and most rigid inspection."

Domestic consumption. What may be the proper and legitimate amount of water for domestic purposes is a complex problem that includes many factors not capable of exact solution, because of their dependence on human habits and social requirements as well as necessities of life.

The accompanying tables give data concerning conditions in several municipalities where accurate and carefully obtained information has been available.

As showing the tendency for increase in the per capita consumption, data from the Boston (Mass.) Metropolitan District is available and comparison of five-year periods are given in table 2. These municipalities are similar in their characteristics and are practically

residential communities; that is to say, they have no large industries which dominate the locality and a very large proportion of the population of all of them have their employment in Boston. These cities have all been fully metered for the past ten years or more. During the past five years the consumptions given in table 2 have been observed.

TABLE 2

Water consumption in residential cities in Eastern Massachusetts, with a complete metered service

MUNICIPALITY	YEAR 1914		YEAR 1918		PER CAPITA CONSUMPTION		INCREASE IN PER CAPITA CONSUMPTION PER YEAR
	Population	Consumption mil. gals.	Population	Consumption mil. gals.	1914	1918	
Malden	48,950	2.237	52,150	3.255	46	62	3.2
Medford	26,430	1.259	34,600	2.161	48	62	2.8
Melrose	16,920	0.933	17,870	1.181	55	66	2.2
Milton	8,630	0.347	9,250	0.435	40	47	1.4
Swampscott	6,770	0.440	7,960	0.606	65	76	2.20
Means and totals	107,700	5.216	121,830	7.638	51.8	62.7	2.18

Increase in population 13 per cent.
Increase in consumption 21 per cent.

In their report (1915) on additional water supply for the city of Providence, R. I., F. P. Stearns and others state (page 6):

> The city of Providence has for many years sold water on a meter basis, and the consumption per capita is low. It is, however, higher at the present time than it was ten or twelve years ago, the increase in per capita consumption being on an average about three-quarters gallon per capita per day.

In a report on the "Enlargement and Improvement of the Baltimore (Md.) Water Supply," J. R. Freeman and F. P. Stearns state (page 24) it must be recognized "that there is a strong tendency manifest in nearly all the large American cities for the per capita supply of water to increase from year to year."

In his report on "Water Supply for the City of Cambridge, Mass." (1903, page 18), Freeman C. Coffin said:

"The rate of increase in the consumption of water of 5.475 per cent per year or about 30 per cent in five years is higher than that of the increase in population which is 13 per cent in five years. This is explained by the increase in the rate of the per capita consumption or the daily consumption of water by each person; that is, the consumption of water not only increases on account of the increase in population but as the population increases the use of water per person increases," and (page 13): "While the increase in consumption was from 1,626,000 to 8,028,914 (gallons daily) in 30 years or about 5.5 per cent per year the increase in population is from 45,166 in 1872 to 94,152 in 1903 or about 2½ per cent per year or about one-half the rate of the increase in the consumption."

It has been said that there is no basis for establishing a rational system of flat charges, and that such a scale of rates is at best a makeshift, with one man's guess as good as another's. This is, without doubt, an absolutely correct statement, yet a close analysis of the use to which water is put in a small residential community enables some comparisons to be made of the use of water for domestic purposes and of the cost of water to consumers by metered and flat rates. One must, however, bear in mind the fact that such a comparison is not an entirely true index of the amount of water which would be drawn by these same houses were they paying for service under the flat rate system uncontrolled by the meter in the cellar.

In a section which may be profitably under consideration there were 1,878 persons served by 379 connections with the water main system, all of which are metered. The average family was, therefore, 4.9 people, using an average of 25.2 gallons per capita. The district owns and maintains its pipe system but purchases water from the Hartford Water Department, which supplies, maintains and reads house meters and makes collections. By meter rates at 12 cents per 100 cubic feet and a minimum charge of $5.00 per connection, the district paid $3,414.55 for water last year at an average rate of about $9.00 per connection.

Eight years ago the district installed its system of about 5 miles of pipe, mostly of 4-inch, 6-inch and 8-inch sizes, at a cost of about $26,000. An average of fixture rate charges paid to 27 private water companies in Connecticut similar in character to the district under consideration, gives the following rate schedule in force prior to 1918:

	per year
Single family (or faucet)	$6.00
Water closet, one	4.00
Bath tub, one	4.00
Set tubs, two tubs	1.50
Sill cock or use of hose	5.00
Total	$20.50
Extra:	
Additional closet	$1.50
Additional bath tub	2.00
Horse or cow	4.00

By metered rates in use prior to 1918–19 by private water companies in Connecticut, the price charged per 1,000 gallons ranged from 25 cents to 40 cents, with a majority of the companies charging 30 cents.

The amount of water required and its comparative cost at a fixture charge of $20.50 per year and at a metered rate of 30 cents per 1,000 gallons are given in table 3.

TABLE 3

Comparison of fixture and meter rates

RATE GALLONS PER CAPITA PER DAY	TOTAL GALLONS PER DAY	TOTAL GALLONS PER YEAR	AT FIXTURE RATE OF $20.50 PER YEAR	AT METER RATES OF 30 CENTS PER 1,000 GALLONS
			*cents**	*dollars*†
20	100	36,500	56.2	10.95
25	125	45,600	45.0	13.68
30	150	54,800	37.4	16.44
40	200	73,000	28.1	21.90
50	250	91,700	22.6	27.50

* Cents per 1000 gallons.

† Dollars per year.

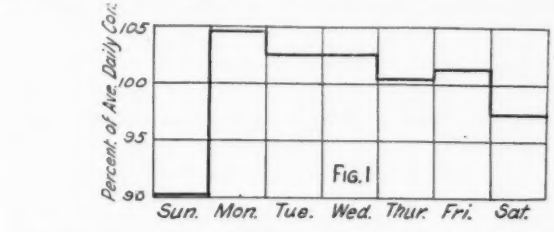
In the district studied, of 48 premises with single faucet only and accommodating 300 people, the average daily consumption was at a rate of 8.8 gallons per day per capita. Of these, 29 premises had a consumption below the average and 19 above that figure. Of the 29 below, 14 had a consumption of 6 gallons per day or less per person and of the 19 above, nine had a consumption of 12.0 or over.

These figures explain in some degree the low rates of water use given for European cities. It appears that without modern con-

veniences, such as bath tubs, water-flushed toilets and set tubs with running water, the average consumption of water per person per day is about 9 gallons.

In full-plumbed houses in this district, and by that is meant those having the conveniences mentioned above, 75 premises accommodating 312 people, used an average of 28.4 gallons per day.

From the above analysis it appears that the cost of metered water ordinarily is cheaper to the consumer than by fixture rates and he is



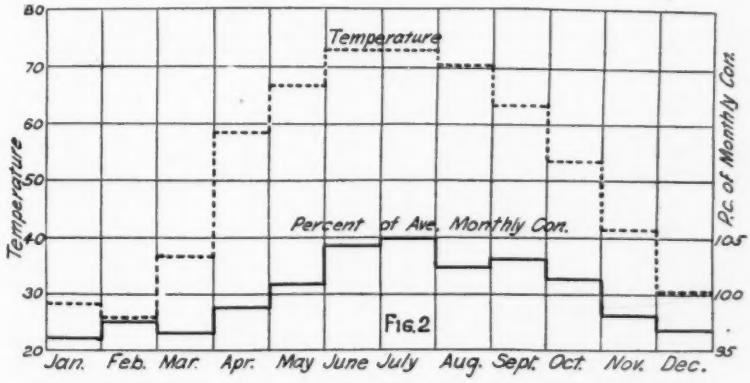


FIG. 1. COMPARISON OF ACTUAL AND AVERAGE DAILY CONSUMPTION

FIG. 2. COMPARISON OF ACTUAL AND AVERAGE MONTHLY CONSUMPTION

thus led to more lavish use. On the other hand the general installation of meters tends to cut down waste of water. The net result of this combination may be that while legitimate household use of water seems to be increasing, the amount pumped or drawn from storage reservoirs is only slowly affected.

The relative consumption of water by months, days and hours is given in figures 1, 2 and 3.

Table 4 shows the use of water in dwellings of various character and conditions of plumbing. That the use of water is concurrent

with these peculiarities is plainly evident by a comparison of the relative amounts of water used in the several houses with the number and kind of plumbing fixtures. Besides the use of water by plumbing facilities the extensive use of automobiles also is a factor which should not be overlooked as it involves the continual washing oftentimes of several machines.

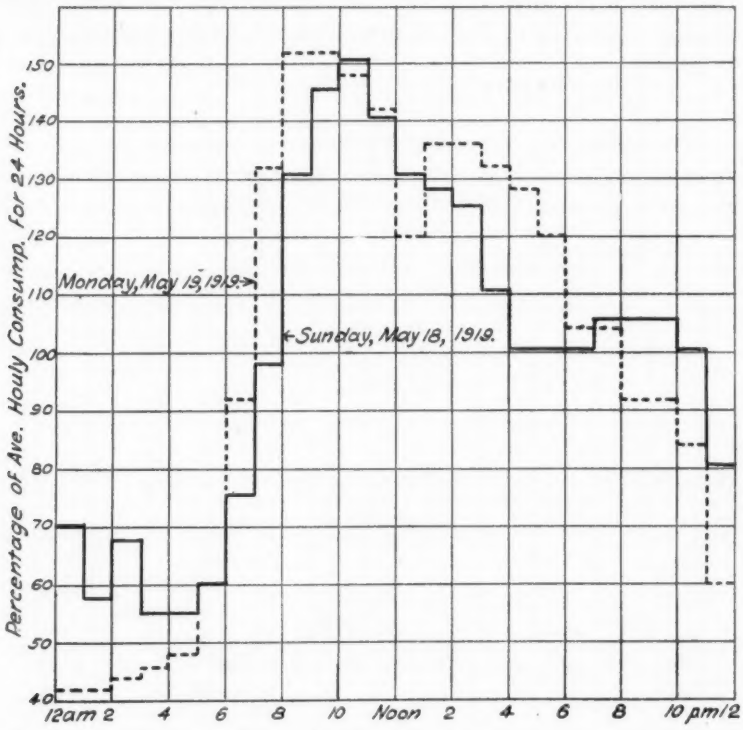


FIG. 3. COMPARISON OF ACTUAL AND AVERAGE HOURLY CONSUMPTION FOR 24-HOUR PERIOD

Note: Average Sunday consumption 8 a.m. to 4 p.m. was 132.9 per cent of the Sunday average. Average Monday consumption 7 a.m. to 6 p.m. was 136.2 per cent of the Monday average.

Table 5 gives a summary of the use of water in 661 premises of various kinds housing 5,937 persons and is believed to be representative of average conditions in Hartford. As all of these premises are metered and have been for a number of years it is reasonable to presume that the use of water in them has become stable.

TABLE 4

Per capita water consumption in houses in Hartford

LOCATION	ASSESSED VALUATION	TANK CLOSETS	FLUSH CLOSETS	WASH BASINS	BATH TUBS	SET TUBS	SHOWER BATHS	NO. OF PERSONS	WATER USED IN 6 MONTHS	GALLONS PER CAPITA PER DAY
Single houses										
1	$45,000	10	None	9	7	3	7	9	28,950	133
2		4	None	4	4	3	None	4	8,600	88½
3	33,000	7	None	8	6	3	2	6	11,800	82
4	3,000	None	2	2	1	2	None	4	7,800	81
5	3,500	2	None	2	1	2	1	2	3,900	81
6	8,000	1	1	3	2	3	1	4	7,200	75
7	25,000	None	7	7	4	3	2	6	9,600	66
8		None	5	4	3	3	1	11	17,000	64
9	1,700	1	None	1	1	2	None	4	6,000	62
10	1,500	1	None	1	1	2	None	4	5,800	60
11	13,000	3	None	3	3	2	None	5	6,980	58
12		1	None	1	1	2	None	2	2,650	54½
13		None	3	3	3	2	1	6	6,300	44
14	2,800	1	1	2	2	2	None	7	5,000	30
15	1,500	1	None	1	1	2	None	4	2,500	26
16	6,000	2	None	1	1	2	None	3	1,800	25
Two-flat houses										
17	4,000	2	None	2	2	2	None	8	8,400	44
18	16,000	4	None	4	3	3	None	4	4,550	43½
19	6,200	1	3	3	2	4	None	7	7,300	43
20	4,200	2	None	2	2	2	None	10	9,800	41
21	7,000	4	None	4	2	4	None	12	10,850	37½
22	8,500	3	None	3	3	4	None	8	7,050	36½
23	6,200	3	None	3	3	2	None	7	5,600	33
24	7,000	3	None	3	2	2	1	10	7,000	29
25	3,000	2	None	2	2	2	None	8	5,249	28
26	4,300	2	None	None	None	1	None	11	7,500	28
27	4,600	2	None	2	2	1	None	7	4,600	27
18	4,500	2	None	2	2	3	None	8	4,850	25
29	5,500	1	2	3	3	2	None	6	3,500	24
30	4,500	2	None	2	2	2	None	15	6,000	17
Three or more flat houses										
31	5,500	6	None	None	None	None	None	31	32,400	43
32	12,000	6	None	1	6	6	None	27	25,600	39
33	89,500	1	17	15	17	6	None	50	40,600	33½
34	5,600	3	None	3	3	6	None	10	6,300	26
35	4,500	3	None	3	3	6	None	17	8,800	21½
36	9,000	6	None	6	6	12	None	25	12,750	21
37	10,000	6	None	6	6	6	None	23	10,100	18
38	4,500	3	None	3	3	6	None	17	6,600	16
39	4,800	6	None	6	6	None	None	19	5,300	12
40	15,500	3	None	3	3	3	None	19	5,280	11

For mixed domestic use 35 gallons per capita seems ample at the present time. For estimate of 10 years hence, 40 gallons per capita per day seems none too small.

The relative character of the houses can be readily observed in the amount of water used per person for domestic purposes. This

TABLE 5

Average conditions of domestic consumption

	SERVICES	PERSONS	CUBIC FEET PER YEAR	PER SERVICE		PER CAPITA
				Persons	Gallons per day	Gallons per day
Apartment houses	9	462	1,394,300	51.4	318	62.0
6 tenement houses	76	1,602	1,987,000	21.0	536	25.5
3 tenement houses	66	828	1,145,400	12.5	355	28.4
2 tenement houses	208	1,543	2,268,100	7.4	223	30.0
Single houses, 3	128	570	866,700	4.5	139	31.2
Single houses, 2	138	743	1,630,100	5.4	242	45.7
Single houses, 1	36	189	748,900	5.3	427	81.4
	661	5,937	10,040,500	9.0	312	34.4

does not mean entirely for personal consumption, as in the case of the single-faucet houses previously noted, but it reflects the more lavish use of water for bathing, automobile washing, lawn sprinkling, etc.

Single dwellings average from 9 to 109 gallons per capita, with ordinary use, as stated above, at a rate of about 35 gallons per capita per day.

INDEX NUMBERS AND SCORING OF WATER SUPPLIES—PART II[1]

By Abel Wolman[2]

In a previous discussion[3] the author presented certain experience data with reference to the 20°C. and 37°C. bacterial contents of filtered chlorinated tap waters, which were to serve as the bases for future studies of similar waters. In this earlier paper it was not possible to develop similar material for B. coli determinations, since the results were not in such form as to be classified by daily values. Since that time, however, the frequency distributions of a large number of B. coli tests have been studied and it was thought desirable to make them available for publication. In this instance, as in the case of the earlier data on total bacterial contents, the material is designed to serve as the basis or guide-post for future comparisons with filtered chlorinated waters.

1. Analysis of observation. As far as the author is aware no attempt has been made hitherto to study the distribution of *daily* B. coli contents in a water supply. The current methods in use for the quantitative interpretation of B. coli tests have made it difficult to obtain values for any but rather long series of results, which fact prevented in general the analysis of observations excepting in mass, as by months or years. In this discussion, use has been made of the McCrady[4] method of the numerical interpretation of fermenta-

[1] Presented before the Chemical and Bacteriological Section at the Montreal Convention, June 24, 1920. Discussion is requested and should be sent to the Editor.

[2] Division Engineer, Maryland State Board of Health, Baltimore.

[3] Journal, September, 1919, page 444.

[4] McCrady, M. H., The Numerical Interpretation of Fermentation-Tube Results, Journal of Infectious Diseases, Vol. 17, No. 1, July, 1915.

Wolman, Abel and Weaver, H. L., A Modification of the McCrady Method of the Numerical Interpretation of Fermentation-Tube Results, Journal of Infectious Diseases, Vol. 21, No. 3, Sept. 1917.

McCrady, M. H., Tables for Rapid Interpretation of Fermentation-Tube Results, The Public Health Journal (Canada), Vol. 9, No. 5, May, 1918.

tion tube results in order to consider the B. coli numerical values for each day during a period of three years. A brief description of the procedure of analyzing the daily results will make clear the advantage in this system of classification.

For our present purposes, the B. coli tests in the tap water of a city of Maryland for the years 1917, 1918, and 1919 were chosen. On each day during this period, B. coli determinations were made by incubating six tubes in each of the three dilutions of 10, 1, and 0.1

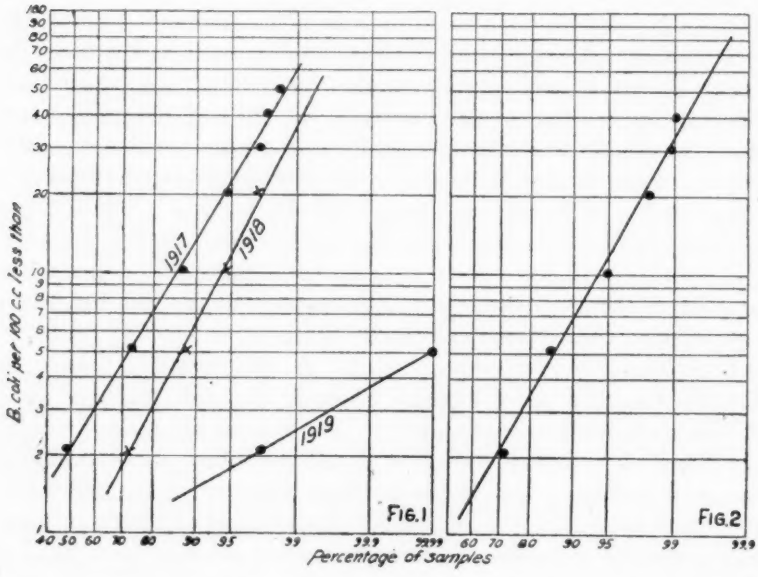


Fig. 1. Frequency-Distribution Records of B. coli in Filtered and Chlorinated Water

Fig. 2. Suggested Maximum Frequency-Distribution Limits of B. coli in Filtered and Chlorinated Water

cc. Lactose broth was used for primary fermentation, plates were made upon Endo medium, with secondary fermentation tests in lactose broth, in accordance with "Standard Methods." From the results in the six tests in each of the three dilutions noted, a numerical value for B. coli content was obtained. The B. coli values thus recorded correspond to what is known as the "completed" B. coli

test.[5] The observations have been grouped then as shown in table 1 and in figure 1. In developing the curves in figure 1 a total of 652 B. coli tests have been used, representing an aggregate of 11,736 initial fermentation tests, all of which naturally have been used in the final evaluation of the data.

It is interesting to note that the values group themselves (fig. 1) according to a definite law. Attention is called to the nature of the distribution of the B. coli results, since this distribution, which is similar to that of the total counts, was not sufficiently emphasized in the author's previous communication.[6] In the case of the bacterial values with which we are concerned, as in many other biological problems, the logarithms of the B. coli contents rather than the bacterial densities themselves are distributed in accordance with the Gaussian or normal law of error. The significance of this distribution in determining accurate methods for the more complete analysis of such phenomena has been emphasized by other investigators,[7, 8] but, in the present problem, these more academic considerations need not concern us.

2. Significance of findings. In order to make the data in table 1 of value as characteristic of "normal" filtered chlorinated tap waters, it is necessary to correct the material by eliminating therefrom all samples which were obtained during abnormal operating periods, such as in intervals of chemical shortage and closing of filtration plant, with use of improperly treated water from temporary sources. Such a correction has been made and the resulting figures are shown in table 2 and in figure 2.

In the light of the United States Treasury Department requirements for water to be used on interstate carriers, it is interesting to examine the data shown on the "standard quality sheet" (figure 2).

[5] Standard Methods of Water Analysis, American Public Health Association, 1917.

[6] Wolman, Abel, Index Numbers and Scoring of Water Supplies, JOURNAL, September, 1919.

[7] Michael, Ellis L., Concerning Application of the Probable Error in Cases of Extremely Asymmetrical Frequency Curves, Science, N. S., Vol. 51, No. 1308, Jan. 23, 1920.

[8] McEwen, George F. and Michael, Ellis L., The Functional Relation of One Variable to Each of a Number of Correlated Variables Determined by a Method of Successive Approximation to Group Averages: A Contribution to Statistical Methods, Proc. American Academy of Arts and Sciences, Vol. 55, No. 2, December, 1919.

The Treasury Department standard has reference to individual samples and gives no indication, for example, of what deviation from the 2 per 100 cc. requirement during a year would be allowable. Such material as here presented offers some means of determining what variation in colon content may be expected in normal

TABLE 1

Variation of B. coli content of tap water

YEAR	TOTAL SAMPLES	TOTAL TUBES	B. COLI PER 100 CC. BETWEEN								
			0-2	3-5	6-10	11-20	21-30	31-40	41-50	51-100	101+
1917	267	4806	132	63	39	19	7	1	1	3	2
			49.4	73.1	87.6	94.7	97.4	97.8	98.2	99.3	100.0
1918	202	3636	146	32	13	5	0	2	0	2	2
			72.3	88.1	94.5	97.1	97.1	98.0	98.0	99.0	100.0
1919	183	3294	178	5							
			97.3	100.0							

TABLE 2

Variation of B. coli content of tap water; corrected values for use in standard quality sheet

YEARS	TOTAL SAMPLES	TOTAL TUBES	B. COLI PER 100 CC. BETWEEN								
			0-2	3-5	6-10	11-20	21-30	31-40	41-50	51-100	101+
1917, '18, '19	614	11,052	441	94	47	20	5	2	0	3	2
			71.9	85.5	95.0	98.0	98.8	99.0	99.0		

NOTE: Upper figures in tables 1 and 2 represent number of samples in each class, lower figures the cumulative percentages of the total number of samples.

operation from day to day. It is the author's opinion, from his familiarity with the material here set forth, that the curve in figure 2 should represent the *maximum* permissible deviations from the "2 B. coli per 100 cc." standard for filtered chlorinated waters, since the observations include several years of plant operation of lower efficiency than it has attained since and which it is assumed it should continue to surpass.

CONSTRUCTION FEATURES OF THE WATER WORKS OF THE GREATER WINNIPEG WATER DISTRICT[1]

By W. G. Chase[2]

The idea of obtaining a pure and practically unlimited supply of water from a visible source not only appealed to the citizens of Winnipeg but also to those of the surrounding municipalities, so that in 1913 the Manitoba Legislature passed an act incorporating the Greater Winnipeg Water District, comprising the cities of Winnipeg and St. Boniface, the town of Transcona, the municipality of St. Vital, and parts of the municipalities of Fort Garry, Assiniboia and Kildonan. The powers and functions of the Corporation are discharged by an Administration Board, consisting of the mayors and reeves of the cities and municipalities, together with four aldermen from Winnipeg, and an alderman from St. Boniface; the mayor of Winnipeg is the chairman of this Board. In accordance with the provisions of the act, the active management of the District has been put into the hands of two commissioners.

Prior to the act of legislature forming the District, the council of the city of Winnipeg appointed a board of consulting engineers to report on the feasibility and cost of a water supply from Shoal Lake, Ontario. This board, Rudolph Hering, Frederic P. Stearns and James H. Fuertes, submitted its report in 1913, recommending Shoal Lake as a source of supply. Briefly summarized, the conclusions and recommendations of the report were as follows:

1. Shoal Lake, without help from the main Lake of the Woods, can be depended upon to furnish, even in the driest years, a large part, if not all, of the water needed for Winnipeg until the population reaches about 850,000; and, with the help of the Lake of the Woods, it can furnish a practically inexhaustible supply.

[1] Read before the Montreal Convention, June 23, 1920. Discussion is invited and should be sent to the Editor. This paper supplements that by James H. Fuertes on the principles of design of the same works, published in the Journal of September, 1920, page 693.

[2] President and General Manager, Canadian Lock Joint Pipe Company, Toronto, Ont., formerly Chief Engineer, Greater Winnipeg Water District.

2. The water of Shoal Lake is of excellent quality for domestic and manufacturing purposes, being soft, practically free from contamination, without noticeable color, free from odors, and of an agreeable taste.

3. The best point to take the water is from the west end of Indian Bay, an arm of Shoal Lake, as the depth of the water and the configurations of the bottom and shores in this neighborhood are favorable.

4. In order to avoid the dark-colored water discharged by Falcon River, and cut off the shallow flowage at the extreme westerly end of Indian Bay, a dyke across the end of the bay and a canal leading therefrom to Snowshoe Bay should be constructed, through which to divert the undesirable waters.

5. The best way to get Shoal Lake water to Winnipeg is to bring it down first through a concrete aqueduct 85 miles in length, laid with a continuous down-grade to a point about a mile east of Transcona, and then through a 5-foot steel pipe to the Red River. A 5-foot cast-iron pipe, in tunnel, is recommended to convey the water under the river, and thence a 4-foot cast-iron pipe, laid in the city streets, to the Winnipeg reservoirs at McPhillips Street.

6. The concrete portion of the aqueduct should be given a capacity of 85,000,000 imperial gallons per day, but the pipe line portion should be given the smaller sizes above stated, capable of discharging 25,000,000 gallons per day by gravity into McPhillips Street reservoirs.

7. It is recommended that the water be taken out of Shoal Lake by gravity rather than by pumping it over the summit in pipe lines.

8. The total cost to the Greater Winnipeg Water District of building the intake, Falcon River Diversion Works, concrete aqueduct and steel and cast-iron pipe lines, including crossings of streams and rivers, waste weirs and other appurtenant works, will be $13,045,600. This estimate does not include the cost of acquiring land, or of branch pipes to the different communities; neither does it include any allowance for water damages, nor for interest charges.

9. It is recommended as a part of the plan, but not for immediate construction, that a new storage reservoir, holding about 250,000,000 gallons and estimated to cost between $300,000 and $400,000, be built at a point about a mile east of Transcona, and that a main pumping station be established to force the water to the city through

the 5-foot steel pipe, and through branches to be laid to the different sections of the city and district requiring the water. This reservoir and pumping station should be completed and ready for use before the demands for water reach the gravity capacity of the steel pipe line.

Final location of route. The organization of the Water District being completed, the work was immediately undertaken and was actively pushed in an effort to complete it within the time limit laid down in the original report of the consulting engineers, with the double object of gaining the use of the new supply as early as possible with its benefits to the individual and of minimizing the capital charges for interest during the construction period. During the winter of 1913–14 the route for the easterly 85 miles of the aqueduct was finally located, five survey parties being engaged from October 17 until March 1. The method followed in general was a system of surface profiles on surveyed road allowances running north and south with occasional profiles on east and west lines. The information so accumulated was completed, contour lines were developed, and the line was projected on a plan, following, as nearly as possible, the principle of a westward slope when it could be obtained, as for instance, along the valley of the Birch River which was followed for 15 miles. Trial lines were then run in the field and cost estimates were computed in the usual way. The line finally chosen was but 8 per cent longer than an air line between the intake and the reservoir site and 35 per cent of it is practically on the average slope, that is, the most economical. During this study there were run 362 miles of transit lines, 1317 miles of level lines, 96 miles of precise levels fixing bench marks for reference from point to point, 380 square miles of topography and 2½ miles of earth soundings. The average gradient is 0.62 feet per 1,000 feet; the lightest gradient, 0.11 feet per 1,000 feet; the heaviest gradient, 1.55 feet per 1,000 feet.

Preparatory works. During the season of 1914 there were undertaken and completed the following works: An earth-filled dyke 1½ miles long, built in about 14 feet of water for the purpose of excluding from the intake waters the discharge of the swamp-fed Falcon River, whose color was very dark; a standard-gauge railway with 102 miles of trackage upon the right-of-way chosen for the aqueduct; and a telephone line of No. 14 copper on wooden poles.

Falcon dyke. The Falcon River dyke is a structure designed purely as a guiding wall to divert the flow of the Falcon River across the westerly end of Indian Bay into an adjoining body of water, Snowshoe Bay, through a canal across the neck of land separating these two bays. The material for it was obtained from a suitable deposit of sand located a few hundred feet north of the north end of the dyke. It was excavated with steam shovel and delivered by means of dinky and 4-yard cars into place. The building of a trestle was avoided by the use of a scow held out from the advancing end of the dyke with heavy stringer timbers upon which the railway track was extended; the full cars were backed up over these stringers, were dumped at the end of the dyke and the empties were run out on to the scow until the train had been discharged. This method was continued until the southerly shore was reached, when the scow was removed and a light shallow trestle of short length permitted the closure of the dyke against the shore. The easterly exposed face of the dyke was heavily rip-rapped with rock from a borrow pit located at the north end of the structure. A light course of rip-rap and planting of willows will protect the westerly face of the dyke.

The effectiveness of this dyke in permitting the bleaching of the waters of the Bay was early in evidence, the color of the water dropping from 150 to 15 and to 10 before the dyke was completed. The color of the waters in Shoal Lake is lighter than that of the waters of the Lake of the Woods, with which Shoal Lake is connected, and for the reason which may be seen at a glance from the study of the following table:

Drainage area of Lake of the Woods, square miles	27,000
Surface area of Lake of the Woods	1,250
Ratio of drainage area to surface area	21.6
Drainage area of Shoal Lake, square miles	360
Surface area of Shoal Lake, square miles	107
Ratio of drainage area to surface area	3.5

It is evident that the waters of Shoal Lake are exposed to the bleaching action of sun and winds for a much longer time than are those of the Lake of the Woods.

Railway. No great difficulty attended the construction of a railway, although most of the route was swamp-covered and surface drainage was a first essential, the country being so flat. The grade

was built up from side borrow entirely, and for several miles this borrow consisted of nothing more than peat, particularly on the summit of land separating Lake of the Woods from the Lake Winnipeg drainage. Gravel pits were found at convenient intervals and the work of ballasting was about 80 per cent completed at the close of the season.

The construction of this railway was a sine qua non of the successful building of the aqueduct. The country traversed was virgin land between miles 40 and 96 and nearly altogether swamp covered. No highways were available for the transport of material for construction nor could any be built cheaply; railway transport was recognized immediately as the key to rapid construction of the aqueduct.[3]

The railway has also been recognized as an essential of maintenance of the water supply and it has behooved the management of the Water District, since they must operate the railway, to encourage the development of the natural resources along the route. These are fortunately numerous, consisting of large deposits of sand, gravel, a fine quality of granite, large quantities of wood fuel, and the land when drained and stripped of growth is a very fertile and productive soil; the settlement of this land is being encouraged and it is not at all unlikely that at an early date the railway as such may be considered a self-supporting entity.

The telephone system was in many sections built twice, as it was almost impossible to distribute the necessary poles; the wire which had been transported on men's backs was first strung on convenient tree stumps until the completion of the railway permitted the erection of a proper telephone structure.

Right-of-way. The right-of-way chosen was generally 300 feet in width from the reservoir site near Transcona at Mile 13 to Mile 74; thence to Mile 84, the Birch River forms one boundary; and thence eastward to the intake the general width chosen was 500 feet, chiefly because the maximum depth of cut necessary for the crossing of the height of land was in the neighborhood of 23 feet and the material to be excavated consisted of 7 feet of peat, 10 to 15 feet of sand and

[3] The magnitude of the construction work is indicated by the following approximate figures of the more important quantities: Earth excavation and backfill, 7,500,000 cubic yards; rock excavation, 16,000 cubic yards; concrete, 455,000 cubic yards; reinforcing steel, 10,000 tons; Portland cement, 575,000 barrels.

sandy clay to a waxy clay floor; that the accommodation afforded by so wide a right-of-way was warranted by the experiences of construction, for numerous slides occurred, spoil from which had to be thrown in places over 150 feet away from the trench.

District supplied concrete aggregate. To attain rapid construction, it was early determined that the work should be let in sections of moderate length; this policy also encouraged the engagement of local contracting organizations but it required the Water District itself to operate the system of transport and to excavate and supply the sand, gravel and crushed stone for the manufacture of concrete. Gravel pits of a satisfactory quality were not to be found convenient to each 18- or 20-mile stretch of the structure; and confusion would have been the result from any effort toward the sub-division of the responsibility either for the supply of material or for the transport of plant and material. The Water District therefore selected, after test, two satisfactory sources of sand and gravel supply and throughout the major portion of the time of construction the District supplied a mixture of sand and gravel concrete aggregate upon platforms opposite the contractors' working points. The policy of supplying mixed material not only minimized the quantity of rolling stock necessary for the work but also assured the use of a uniform material throughout the entire mileage of the aqueduct. The difficulties of inspection of concrete making and mixing were also greatly diminished thereby, and the cost to the contractors for the manufacture of concrete was necessarily less than would have been the case had sand and gravel or crushed stone been supplied separately.

In determining the quality of this uniform concrete aggregate, a series of laboratory tests was carried out during the winter of 1914–1915 in an effort to determine the mixture of Portland cement and of aggregate for the production of a concrete which would be watertight, sufficiently strong in compression and at the same time not wasteful of cement. These experiments were carried on with mixtures containing only one barrel of Portland cement per cubic yard of concrete and it was ultimately determined that by the use of a proper proportion of dust or fine sand in a fairly graded sand a 6-inch wall of concrete could be made impervious to water under pressure of 80 pounds per section inch, the test standard adopted. Recently investigators have been able to make 1-inch slabs impervious against similar pressure and by similar means. This subject was discussed in a paper read by D. L. McLean and the author before the Engineering Institute of Canada in 1915.

The Water District, having determined upon the policy of supplying the sand and gravel to the contractors, determined also to supply the necessary Portland cement under purchase contracts and thereby to ensure a uniform cement for the entire project. Such a supply was obtained in Winnipeg from the mills of the Canada Cement Company and by virtue of the local sources being available the supply was kept steady and deliveries were prompt as required. Storage of cement by the District was thus avoided.

The total traffic over the District railway during the period of construction was fairly heavy. Carloads of aggregate contained 23 cubic yards each or a total weight of 130,000 pounds per unit. The rate of consumption of concrete materials ran as high as 1200 cubic yards per day and the principal source of supply was located at Mile 31. Throughout the entire construction approximately 1,000,000 cubic yards of sand and gravel were moved for concrete manufacture, for building up trench foundation where firm soil was at too low an elevation, and for backfill where native and local materials were scarce. This traffic was in addition to the haulage of Portland cement, about 600,000 barrels, the distribution of contractor's plant and the transport of passengers. A tri-weekly mixed train served to distribute plant, cement and to meet the requirements of passenger movement; additional trains handled the sand and gravel.

Intake. The site chosen for the intake is a rock cut on the peninsula which forms the north end of the dyke above described. Gathering walls of rock fill over a sand core were extended about 200 feet into the lake to permit the draught of water from a sufficient depth. A concrete chamber located in the rock cut houses the trash racks, the screens, the sluice gates and stop logs which permit the control of waters discharged into the aqueduct.

During construction a cofferdam of sand across the opening between the gathering walls provided the shelter for the rock excavations. This type of cofferdam, easily protected, maintained and easily removed, was quite satisfactory.

Aqueduct construction. Speaking generally, each contractor endeavored to keep his work concentrated at each camp, and, except for backfilling operations, the excavation, trench trimming and aqueduct building were confined within a distance of one-half mile in each case. The number of camps per contract varied from two to five, depending upon the possible rates of construction. The

total number of camps during the successive years were: 1915, eleven camps; 1916, fourteen camps; 1917, twenty camps; 1918, twenty-two camps; besides those operated at the District's source of material supply, three in number. The maximum number of men engaged upon the project was about 2500.

Earth handling. The methods of handling earth varied considerably. On the easterly 47 miles Bucyrus draglines in capacities from $\frac{5}{8}$ to $3\frac{1}{2}$ cubic yards, were used for excavating and for backfilling. These draglines were specially designed to be self-propelling, and were supported upon the swamp surface by means of timber pads built in sections, the machine itself being mounted upon rollers.

TABLE 1

A few records of earth excavation from the trench with the various classes of machinery engaged

TYPE OF MACHINE	CAPACITY	AVERAGE DEPTH OF CUT		MATERIAL EXCAVATED	AVERAGE YARDAGE EXCAVATED PER 10 HOUR DAY
	cu. yd.	*ft.*	*ins.*		*cu. yd.*
Marion shovel.....	$1\frac{1}{2}$ (dipper)	12	0	Clay	612
Walking dredge.....	1 (dipper)	8	0	Clay	745
Bucyrus dragline....	1 (bucket)	6	0	3′ peat, 3′ sandy clay	640
Bucyrus dragline....	1 (bucket)	7	5	1′ top soil, 6′5″ fine sand (wet)	740
Bucyrus dragline....	1 (bucket)	9	0	2′ peat, 3′ fine sand, 4′ sand and gravel	900
Bucyrus dragline....	2 (bucket)	14	0	12′ peat, 2′ clay in bottom of trench	1950
Bucyrus dragline....	$3\frac{1}{2}$ (bucket)	18	5	6′ peat, 12.5 clay	2920

Between Miles 31 and 51, a few steam shovels were used with greater or less success; these were supplemented by drag-lines. Between Miles 13 and 31, walking dredges, figure 1, were used; here the cut was generally shallow and the soil fairly firm. Each type of machine had its advantages but speaking generally the dragline seemed the most suitable device. Table 1 gives some records of their work.

Throughout the easterly 47 miles the spoil of excavation was dumped close to the trench and formed into an elevated grade for the dinky railway track used to distribute the mixed concrete. Earth so placed was convenient for backfilling but was occasionally the cause of slips of the trench wall, in which event the tramway

grade was maintained by means of pole trestles. Payment for the work of excavation was limited to fixed slopes of the trench walls, namely, one horizontal on three vertical in firm soil and one

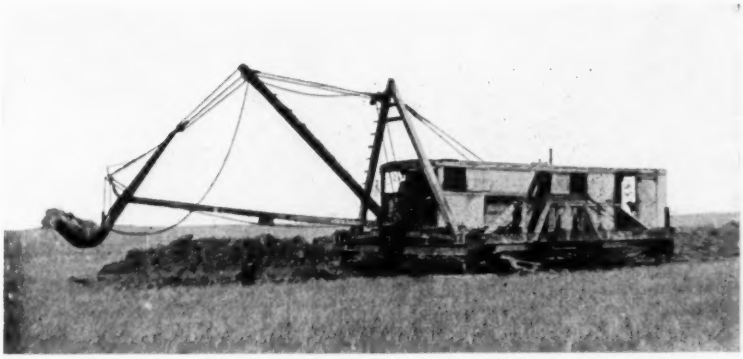


FIG. 1. WALKING DREDGE EXCAVATING TRENCH ON A PRAIRIE SECTION

FIG. 2. REPLACING WITH SAND AND GRAVEL THE MUSKEG MATERIAL WHERE FOUND BELOW THE GRADE LINE

horizontal on one vertical in soil which would not stand on steeper slopes. Machine excavation was permitted to within 6 inches of the determined floor grade, and it was required that the remainder of the earth should be removed by hand.

FIG. 3. LOWERING AN 8-FOOT LENGTH OF 66-INCH LOCK JOINT PIPE INTO THE TRENCH

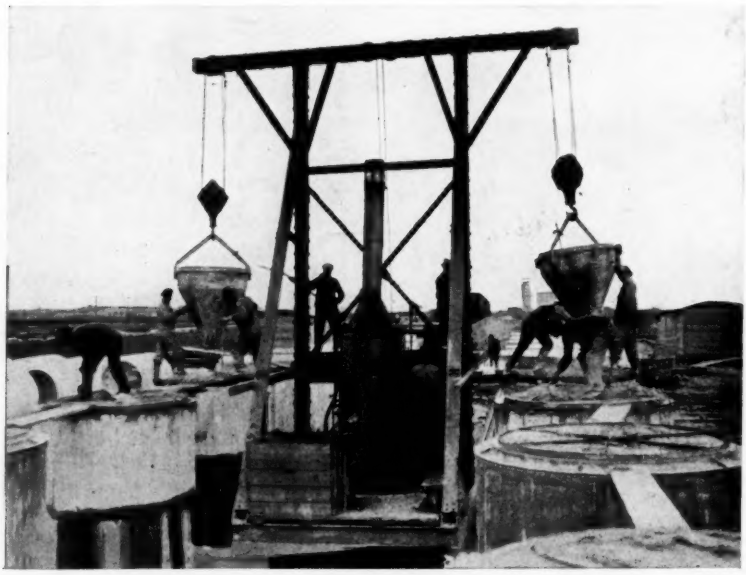


FIG. 4. GANTRY DELIVERING CONCRETE TO FORMS FOR 66-INCH PIPE, CAST IN 8-FOOT LENGTHS WITH 8-INCH WALLS

As all of the trench grade lay below the ground water level the problem of handling ground water seepage and trench floor seepage was constantly a prominent one. Notwithstanding this fact it was possible to obtain compliance with the requirements of the specifications that all concrete must be "laid in the dry." This was accomplished by means of a system of side-wall trench drains and of a centre line depressed drain lined with a wooden box with transverse cover slats, surrounded with coarse gravel or broken stone. Diaphragm pumps operated by gasoline were successful in maintaining the ground water below the grade of the trench floor. Trimming of the surface of the earth for the reception of concrete was not permitted until the hour of concrete placing, and by observance of this rule the preservation of a firm surface for the receipt of concrete was assured.

Foundations. The material encountered in this hundred miles of trench work varied all the way from peat to rock, including soupy clay, waxy clay, the various intermediate mixtures of clay and sand, sand dry or under water pressure and quicksand, granite and trap rock. By care in location, therefore, little rock excavation was necessary anywhere. Each class of soil found at invert grade presented a separate and distinct problem in the effort to obtain a highly resisting trench floor. Dryness was a prime essential and was generally obtained by the methods described.

Soupy clay was made firm by casting into it broken stone of varying sizes, mostly of the riprap dimension.

Quicksand was excavated below grade between lines of sheet piling, a layer of stone and gravel was superposed, and within this layer the box drain was maintained at its proper grade. This stone served to prevent the movement of the sand as the water escaped upward from the sand, and also provided a foundation satisfactory for the support of concrete maintained dry until set.

In rock cuts a floor of sand was generally placed, as the length of each cut was small.

Where the peat beds were found to extend to depths below the grade chosen for the invert of the aqueduct, the trench was widened and the peat was taken out to whatever depth it would extend, figure 2. Sand and gravel were then placed in the bottom of the trench under water, and after having built this bed to about 2 feet above invert grade it was underdrained and allowed to settle. The bed of sand was then trimmed in the ordinary way, and a strong foundation was thus provided.

In the case of flowing clay foundations, it became necessary to open the trench wider than for the standard structure, and in some cases to build piled foundations and use a heavily reinforced invert. Great care was necessary in backfilling in such trenches to prevent the transmission of pressures irregularly to the structure.

Along Snake Lake, which parallels the aqueduct route for 2 miles near the intake, and at certain other points, a porous foundation would have been the source of a serious trouble inasmuch as the surface waters would stand higher than the structure itself and the structure when empty would be liable to float. Generally along such locations the material available for backfill use was of a peaty nature and light in weight. The precaution was here taken of building a heavily weighed invert; the engineer's judgment was constantly at test as to whether a weighed invert should be considered necessary or not. With a structure 10 feet 9 inches wide inside, the expense of such an invert was very great and was avoided wherever the earth of the trench floor seemed fairly tight. In deciding upon the use of a weighted invert for this purpose, the following options were discarded for the reasons set out:

a. Imported backfill of earth; too expensive.

b. Increased overfill; of doubtful effectiveness and necessarily huge in quantity.

c. Weighted arch or superstructure; not very efficient and would require a very sturdy invert.

The success of the design chosen and the efficiency of the supervision maintained have been proved through the first year's operation, as the aqueduct through these locations is still secure in place, although frequently far from full of water and although it has been constantly wholly submerged.

Backfilling. The specifications required that between the walls of the trench and the aqueduct the earth backfill should be tamped carefully to a depth of 4 feet. This precaution was taken in conjunction with a moderately light design of arch, which arch, however, was quite safe against pressures of earth backfill even without packed earth at the haunches. In cuts wholly in muskeg, it was impossible to carry out such a specification. In a few cases, a slight addition to the thickness of the arch haunches was provided, but generally the only precaution taken was the deposition against each haunch of imported sand and gravel to the depth prescribed.

The backfill was then completed with a machine, generally the machine used by the contractors for the excavation of trench. It was piled to a depth of 4 feet upon the crown in the case of solid earth, or of 5 feet in the case of peaty material. The minimum width of backfill top prescribed was 8 feet, or where that was exceeded by the clear inside width of the aqueduct then that width became the governing dimension for the top of the backfill. The side slopes of backfill were one and three fourths horizontal on one vertical, a slope which proved to be satisfactory. The only modification made in these side slopes was along Snake Lake, where high waters of the lake would rise upon the face of the slope; here the slopes were made three horizontal on one vertical.

The backfill was grassed over with a selected mixture, very heavy sowing of seed assuring a thick bottom on moist soil and insuring a catch on the driest sections. Most of this seeding on the easterly 50 miles of work was done by contractors; but a considerable acreage of the westerly portion of the line has been seeded by Water District forces this year. The seeding operations included the removal and burning of stumps and other combustible rubbish, removal of stones, trimming and crowning of the backfill and the raking and rolling of the seed bed. The work done by the District was generally on firm material well settled during the two or three years which had elapsed since the building of the backfill. This backfill was thoroughly stirred up with specially designed harrows built to hold themselves on the summit of the dump. No rolling was done but the seed was well buried, a shelter crop of grain being planted at the same time.

Concrete making. Throughout the work of aqueduct construction, control of the mixture of sand and gravel was maintained by the District's engineers through careful inspection and direction of the operation of the District's own gravel pit where the excavation, screening and re-mixing of the sand and gravel were carried on, producing a uniform concrete aggregate with the desired proportions of sand and dust. It must be remembered the prime objective in the manufacture of concrete for this conduit was water-tightness with economy in the consumption of Portland cement. This material when dry weighed about 122 to 125 pounds per cubic foot or with 4 per cent moisture, a common condition, 110 to 112 pounds per cubic feet. About 29 cubic feet of aggregate was sufficient to build one cubic yard of concrete in place, allowing for all waste both of aggregate and of concrete. The average consumption of Port-

land cement was $1\frac{1}{4}$ barrels per cubic yard for all work in the 100,000,000-gallon section of the water supply scheme, the easterly 85 miles. The consumption of Portland cement in the pressure pipe of the Red River Valley siphon was about 2 barrels per cubic yard in a mixture averaging about one bag of cement, $1\frac{1}{2}$ cubic feet of sand and $2\frac{1}{2}$ cubic feet of gravel not over $1\frac{1}{4}$ inches in diameter.

Generally speaking, the invert of the aqueduct was laid in pads of 15 feet length, alternate pads being first laid and when these were hardened the closures being placed. The process of invert making included the placing, tamping and screeding and the floating and trowelling of the surface exposed to water flow. The shoulder was built to a level plane at the chosen elevation, its inner margin being about 1 inch within the wall of the arch at its foot. This practice afforded a clean and definite line of intersection between the inner surfaces of the arch and the invert. Into the green concrete of the shoulder a thin wooden strip was placed and bound by the setting concrete. After the concrete had set and before it became hard, this shoulder was brushed with wire brushes removing all laitance and exposing the pebbles of the concrete.

The arch was commonly built within 45-foot forms, each set of forms being arranged for transport up and down the trench upon a suitable carriage. The bulkheads were designed to support and to secure the beaded copper strip water-stop. As the trench was commonly in shallow cut, it was necessary to mix the concrete with some slight excess of water although the presence of the fine sand in the aggregate gave a considerable fluidity to the mixture. It was therefore necessary to work the concrete carefully into place in the form and, after filling the form, to keep adding concrete, at the same time working the material off the surface of the crown of the inner form until the material became too stiff for further working. After the first season of construction, it was found that this precaution ensured the building of an arch structure without longitudinal crown cracks, a common distressing difficulty in all arch building especially where the crown is thin and the arch form flat or of large radius.

River crossings. The conduit crosses the Falcon River close to the discharge of that stream into Indian Bay, and about 4,000 feet west of the intake. It crosses the Birch River three times at Miles 82, 78 and 74, the Whitemouth River at Mile $64\frac{1}{2}$, the Brokenhead River at Mile 41, the Seine River at Mile 4, and the Red River at

Mile 3. Crossings of the Falcon, Birch, Whitemouth and Brokenhead Rivers are inverted siphons of reinforced concrete built in the trench and designed with a loss in head conformable to the average loss in head for the same distance in the horseshoe structures between which it is interpolated. A Venturi meter is built in place with the Falcon River siphon, the superstructure or register chamber being frost-proofed with earth covering in the shape of a huge truncated cone. At the first and third Birch River crossings and at the Whitemouth and Brokenhead crossings, an overflow was provided combined with provision for cutting off the flow in the structure. Ingress and egress for small boats is provided at each river crossing. A weir built in the side of the conduit at each of these regulating points, as also at Mile 17, is of sufficient length to permit the discharge of the entire capacity of the aqueduct with but small rise in head. It is frost-protected by discharging into the bottom of a well from the lip of which the water is discharged through a culvert into the river, or in the case of Mile 17, into an 11-mile overflow ditch.

The Seine River lies within the Red River Valley and is parallel to the Red River at the point of crossing by the conduit. The Red River Valley inverted siphon begins at Mile 17 and discharges into the reservoir of the city of Winnipeg on the west side of the Red River $2\frac{1}{2}$ miles from the city. Four miles west of the east end of this siphon is located a site for a future 250,000,000-gallon reservoir, as the land surface there is at a convenient elevation for the building of an earth contained basin, and to this point the capacity of the siphon is 100,000,000 gallons per day. The westerly twelve miles of the siphon has a capacity of 60,000,000 gallons per day by aid of a booster pump at the Red River margin or of 32,000,000 gallons per day by gravity. Ultimately a second line of similar capacity from the Water District reservoir to the centers of distribution in the Water District will be laid to care for the maximum daily demand. Local reservoirs within the Water District will provide the balance between the maximum daily demand and the maximum hourly demand.

The easterly four miles of this Red River Valley siphon is a 96-inch diameter reinforced concrete pipe with 8-inch wall, trench-built in 15-foot sections and in the standard two portions, namely, invert first and superstructure following. The transverse joints were ultimately calked with a V of neat cement hammered into

place. The backfill over this 96-inch pipe and over the other circular pressure pipe at easterly river crossings is 6 feet in depth, it being more important to prevent frost forming within the pressure pipe whose perimeter is entirely wetted than within the horseshoe section whose crown is never wetted.

Between the Red River margin and the site chosen for the Water District's reservoir at Mile 13 the conduit is a 66-inch diameter lock-joint reinforced concrete pipe with 8-inch wall, manufactured at a central point and in 8-foot lengths, transported to the trench on railway cars and laid and jointed in the trench, the jointing not being done until the pipe had been covered to a depth of one foot with earth and had obtained a uniform temperature.

This trench was very interesting. The contract provided for vertical payment lines and the contractors decided that for convenience in operations those payment lines must also be the construction lines. The first operation was to drive 20-foot round wooden piles along each side of the trench and at intervals of 2½ to 4 feet. These piles afforded support for the steam shovel with which the earth was removed from the trench and also ensured that the berm of the trench should be firm and capable of supporting the machine with which the heavy pipes were lowered into the trench. The entire process of excavating, pipe laying and preliminary backfilling was confined within a distance of less than 500 feet as a rule. Backfilling to a depth of one foot above the pipe followed immediately after the laying of the pipe to line and grade and the building of supporting haunches of plain concrete alongside the pipe. The trench wall piling was then withdrawn and the piles were carried forward for second use.

This Red River Valley siphon passes through a soil bed whose sea-deposited clay is heavily impregnated with sulphates of sodium, of magnesium and calcium and bearing occasionally some other salts. To prevent reaction of these salts in ground waters upon the reinforced concrete pipe, this trench, from Mile 13 to the Red River, and its extension through the city of Winnipeg from the Red River to the city reservoirs, was thoroughly underdrained. An 8–inch vitrified tile was laid with open joints along the lower corner of the trench and, after the shoulders or haunches of the concrete had been built alongside the pipe in place, a backfilling of coarse gravel was placed nearly to the top of the shoulder, ensuring the collection of water from the trench walls and its delivery to the drain tile.

No serious difficulty attended the construction of this ten miles of lock-joint pipe line. At places such as in the crossing under the Seine River bed, at railway track crossings, and where the earth banks showed a tendency to slip, the wall piling was left in place, along with a small quantity of shoring.

Similar methods of construction were applied to the 48-inch diameter reinforced concrete lock joint pipe line with 6½-inch wall laid from the west shaft of the Red River tunnel to the City of Winnipeg reservoir on Logan Avenue, a distance of 2.3 miles. This pipe was manufactured in 10-foot lengths.

All the lock-joint pipe was manufactured in a yard at Transcona, one mile north of the line of work but convenient to railway tracks for the receipt of reinforcing steel and of cement. This yard was laid out as a double-ended plant and the two longitudinal halves of the yard were duplicates in most particulars. Eight Little Wonder concrete mixers served the yard and permitted the manufacture of an average of about thirty lengths of 66-inch pipe per day. The reinforcing mesh, delivered in 46-inch widths and incidentally the heaviest mesh ever manufactured, was bent to shape in special rolls located on one side of the middle of each end of the yard. The square twisted steel bars used in manufacturing the interior cage of reinforcement were bent to shape and assembled in cages on the opposite point of the yards. The pipes were cast within steel forms set up upon a double line of concrete bases reaching from end to end of the yard. Provision was made for the admission of steam to and about these forms. After the pouring had been completed, steam was furnished from a boiler plant located in the middle of the yard.

The mixed concrete was transported from the mixers at the ends of the yard to the forms by means of a specially designed travelling derrick or crane, figure 3, whose outrigger arms supported conical concrete buckets which discharged through a plug valve in the bottom of the bucket on to a circular disk set upon the inner form of the pipe. The pipe was cast spigot end upward, a special form being provided for the formation of the spigot and for the support of the copper water stop during the process of pouring.

Storage of the pipe after steam curing was provided along each side of the yard, the pipe being laid upon its side upon transverse runways. It was loaded for shipment upon cars spotted on tracks lining the outer edges of the storage yard.

Red River tunnel crossing. The Red River is crossed with cast iron pipe 60 inches in diameter, set within vertical shafts lined with concrete, and within a concrete-lined horizontal rock tunnel 10 feet square. Complete valve control is provided at each end. On the easterly end a reinforced concrete circular surge tank with concentric receiving tank was built, the whole being housed in for frost protection within a masonry shell. The construction of this work afforded very few difficulties. One notable feature, however, was the method adopted by the contractors for the support of the walls of the excavation for the receipt of the surge tank. The floor was about 20 feet below the surface of the ground. This support consisted of a sixteen-sided timber mitered framing without shoring, dressed with vertical sheeting. This arrangement gave clear access to the whole of the interior and was a perfectly safe protection for the 50-foot diameter excavation. The well structure is supported on concrete piers sunk to rock.

The shaft lining, of 2-foot reinforced concrete circular wall, was shod with heavy steel plate and was built in sections as the lining was sunk by excavation from within. It proved easy to maintain this 16-foot shaft in a vertical position on center.

The cast iron pipe lining of the tunnel proper was designed in 8-foot lengths with a special interior calked joint. Calking was done with lead wool.

The backfilling of concrete around the pipe in the tunnel was done through tremies consisting of 4-inch well holes sunk from the surface of the ground or through the bed of the river as the case might be. A 150-foot length of tunnel was refilled at each stage, concrete being built up to within about 1 foot of the roof of the tunnel excavation, and the remainder of the cavity being filled with mortar. The mortar was poured continuously down one tremie until it rose to at least river level in the other tremies entering the section. This ensured the sealing of the tunnel solidly under heavy pressure.

Concrete in alkali soil. This is a subject of vast importance to the municipalities and other owners of concrete structures throughout central Canada and central United States. The injurious elements found in the soils are the sulphates of metals, viz., magnesium, sodium and calcium, and these sulphates in the presence of ground water attack the concrete from the outside transforming it into a sulphate of calcium, destroying its cohesion and ultimately wrecking the structures. Unfortunately this is proved from the experience of the cities of Winnipeg and St. Boniface with concrete sewers; of

building owners with respect to foundations in Saskatoon, Moose Jaw, Winnipeg and other cities; and of owners of irrigation projects who are losing their canal linings, their controlling works and their concrete siphons or pressure pipes.

The engineers of the Water District after 1916 took the precaution of providing underdrainage for the trench carrying the pressure pipes of the Red River Valley inverted siphon, as about that time it became evident that it is very doubtful whether Portland cement concrete of any consistency, strength or density, porosity or permeability is safe against the attack of these ground-water solutions of sulphate salts. A portion of the 100,000,000-gallon structure, between Miles 13 and 17, a 96-inch diameter concrete pipe with 8-inch wall is now found to be suffering decay on its surface from

TABLE 2

Meters on the Winnipeg Aqueduct

METER	PIPE DIAMETER	THROAT DIAMETER	MEASURING
	inches	*inches*	
1	108	42	Draft from lake
2	96	37	Delivery to main reservoir
3	66	29	Draft from main reservoir
4	24	16	Delivery to St. Boniface.
5	36	20	Delivery to Winnipeg at Red River high pressure pumping station
6	48	28	Delivery to Winnipeg at terminal reservoir on Logan Avenue
7	12	Empire Compound	Delivery to Transcona at reservoir
8	8	Compound	Delivery to Fort Garry via City of Winnipeg mains

these agencies, and the Water District is engaged in a program of sub-soil drainage parallel to the conduit and reasonably close to it in the hope that this drainage, by lowering the ground water plane between the two parallel drainage trenches, will cause the action to cease.

Fortunately, the soils which contain these salts extend over a small area of the country crossed by this important water supply project and a system of ground water tests is being established so that the risk can be continually observed and necessary precautions can be taken from time to time.

Meters. There are eight meters on the aqueduct, located as shown in table 2, by which the distribution of the water is checked constantly.

DISCUSSIONS

COOPERATIVE RESEARCH

The writer hopes that the suggestions[1] made by Mr. Wolman will be fructified and that the American Water Works Association will appoint a committee to devise a plan for systematic research on some of the problems indicated. The clear and concise statement of these, as made by the author, will be beneficial and should act as a stimulus to all interested in the science of water purification.

The two fields of investigation that appear to the writer to be the most fertile are coagulation and sedimentation, and chlorination.

The methods of procuring suitable coagulation are only just being transferred from empiricism to the realm of science and our knowledge of the governing laws is still very meager. With an ever increasing cost of operation and construction it becomes more and more imperative that these laws should be investigated with a view to eliminating waste and providing a basis for economical design.

The investigations made by the writer in the field of chlorination have convinced him that the superficial strata has scarcely been turned over and that further exploration will amply repay those who undertake it. Chlorination has made wonderful progress during the last decade but it cannot be said that the scientific development has kept pace with the mechanical. One problem needing immediate attention is the nature of the substances that give rise to the iodoform-like odor in some chlorinated waters. Several years ago these were ascribed to the formation of chloramines, but we know now that chloramine itself can be used as a sterilizing agent without producing the iodoform odor. Why do some waters give this typical odor with one dosage and none when the dosage is increased? Sir Alex. Houston, who has met with several such instances in his experience with the London supply, has suggested to the writer that the odor-producing and odor-non-producing dosages give two differently oriented chloro-organic compounds, only one of which causes complaints. This is a hypothesis well worthy of investigation.

JOSEPH RACE.[2]

[1] JOURNAL, June, 1920, page 572.

[2] Mansion House, Hereford, England.

DEFIANCE WATER WORKS

Near the upper right corner of the sketch on page 442[3] is shown a standpipe which the writer believes to have been erected there long ago. If so it has an interesting history.—When the water works property was owned by a private company, the writer advised against further expenditures in the immediate vicinity of the pumping station until after that standpipe had been removed, possibly to a distant part of the city where its usefulness would be greatly increased and damages resulting from a second failure greatly diminished.

H. F. DUNHAM.[4]

CEMENT JOINTS FOR WATER PIPE[5]

It is interesting to note the increasing use of cement as a calking material for cast iron water pipe joints. The Water Bureau of Portland, Oregon, began using cement joints in 1916, and up to and including November 30, 1919, has laid pipe as follows:

SIZE	LENGTH	CEMENT	LEAD
inches	*miles*	*pounds*	*pounds*
6	2.7	3,525	2,507
8	5.4	12,040	4,372
10	0.2	1,200	300
12	3.5	11,054	4,411
16	0.3	1,000	1,120
Totals.....	12.1	28,819	12,710

If lead alone had been used for this work it would have required approximately 50,000 pounds of this material in place of the cement. This represents a considerable saving in money, not to mention the fact that it is our opinion that cement makes a more efficient joint.

In addition to the above, in 1917 and 1918, Water Bureau forces took up and relaid for the contractor on the Sullivan Gulch elimination of grade crossings the following pipe: 583 feet of 30-inch pipe, 3,374 feet of 24-inch, 158 feet of 16-inch, 888 feet of 12-inch, and 787 feet of 8-inch pipe. Most of this pipe was relaid with cement joints, and a particularly interesting feature in connection with the 30-inch

[3] JOURNAL, July, 1920.
[4] Civil Engineer, 32 West 40th Street, New York.
[5] JOURNAL, July, 1920, page 436.

was that when this pipe was first laid in a concrete tunnel under the railroad tracks and the pressure turned on the leakage was at that time considered serious. However, after draining the water from the tunnel two or three times in the following few weeks it was noticed that the leaks were becoming less. In about six months from the time that the main was laid the leakage had completely stopped and all of the joints have remained tight since that time.

Recently the general foreman had occasion to lower about 100 feet of 16-inch cast iron pipe having cement joints. This pipe was lowered approximately 4 feet while under full working pressure and no leaks resulted.

The method of making up these cement joints is practically the same as described by Mr. Pracy.

Up to date we have not had to make any repairs to any of our cement joints and it is interesting to note what Mr. Pracy says relative to such repairs.

F. M. RANDLETT.[6]

WATER WASTE CONTROL

The writer wishes to supplement the remarks of Dr. Hale[7] concerning the assistance that can be obtained by the use of laboratory methods. Whilst in Ottawa, Ont., the writer was called upon to examine samples suspected of being derived from leakages and the method finally adopted was to determine the electrical conductivity by means of a Dionic water tester. This apparatus can be assembled and the test completed within two minutes. In the case of the Ottawa supply the low conductivity, about 20 units, made it easy to distinguish it from ground water, well water, and sewage and very few instances occurred in which the results were in any way ambiguous. The writer would recommend this method for cities in which the conditions are similar to those prevailing in Ottawa because of its reliability and speed, the latter being quite an appreciable factor when excavations have to be kept open pending a report from the laboratory. The electrical conductivity test also affords a rapid means of detecting changes in the supply, for the conductance, or reciprocal of the conductivity, is proportional to the mineral content.

JOSEPH RACE.[8]

[6] Engineer Water Bureau, Portland, Ore.

[7] JOURNAL, July, 1920, page 514.

[8] Mansion House, Hereford, England.

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OF THE

AMERICAN WATER WORKS ASSOCIATION

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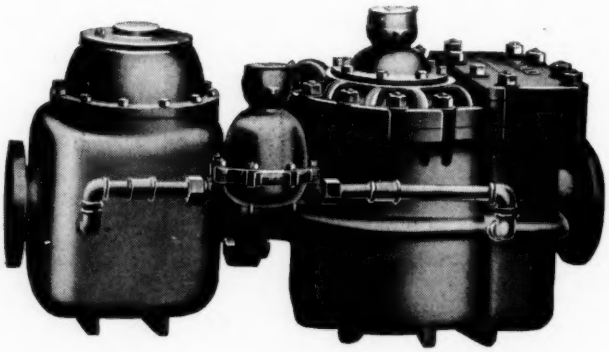

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Combining the NILO VELOCITY and KING DISC Meters and an automatic double differential valve having twice the capacity of the inlet pipe.

Compound Valves may be attached to any meter to catch the small flows and increase revenue.

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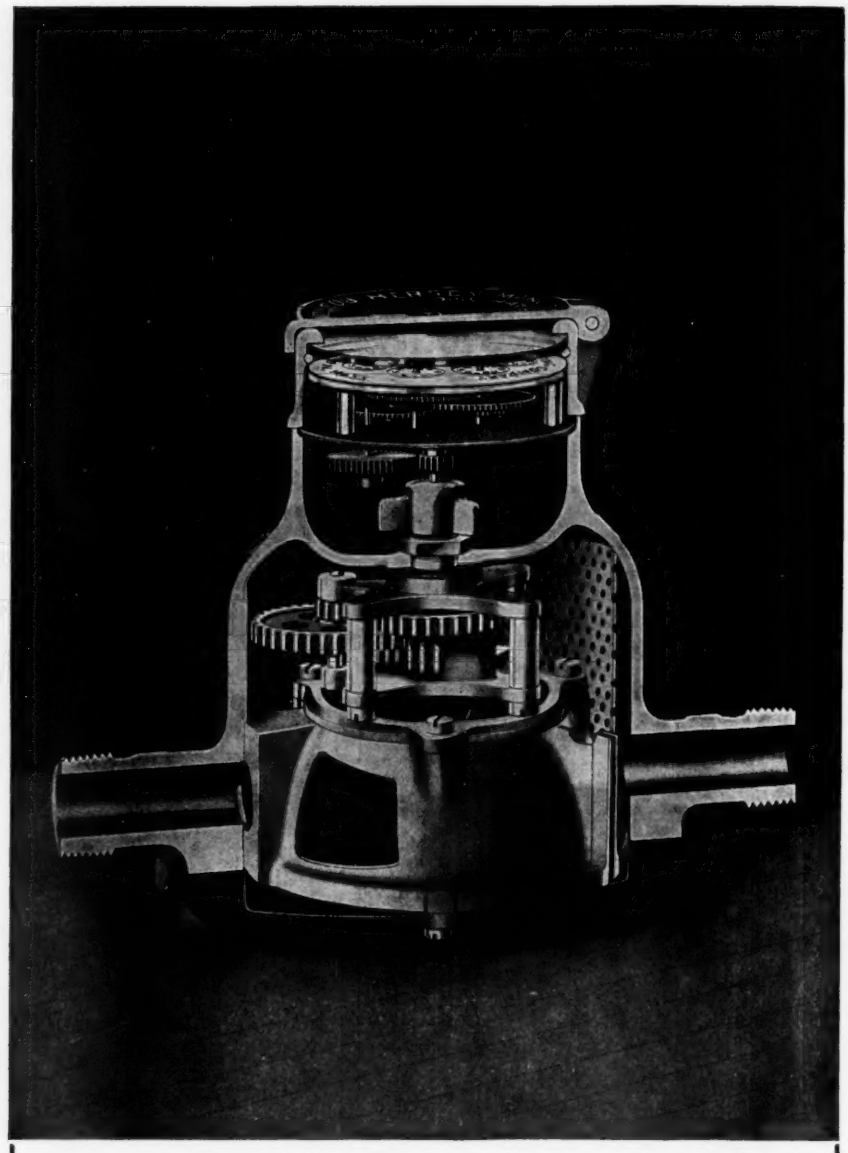

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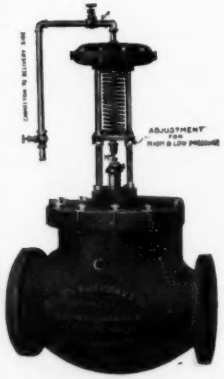

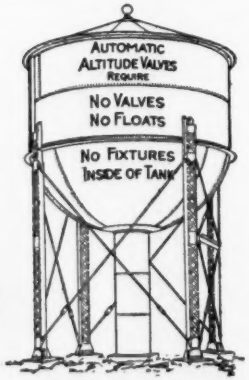

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3.—Contain no floats, fixtures.
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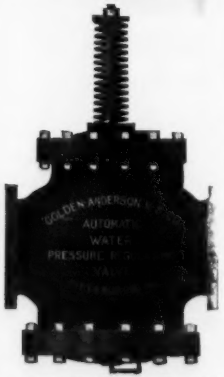

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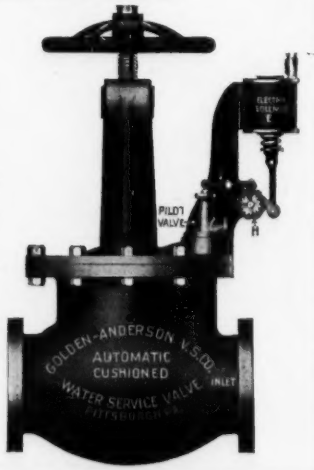

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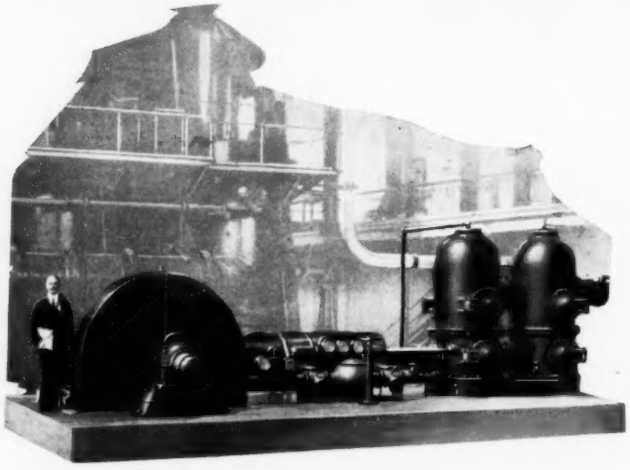

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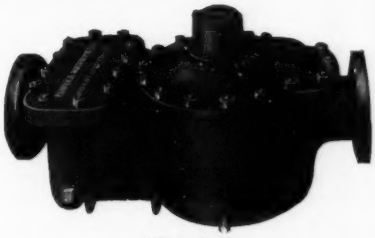

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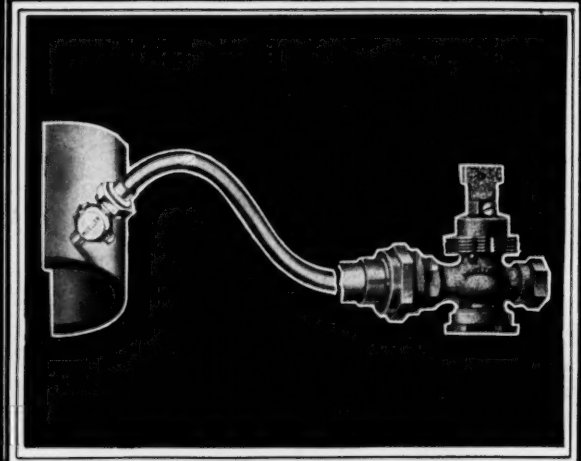

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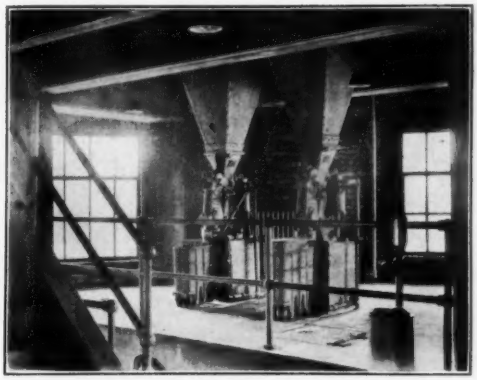

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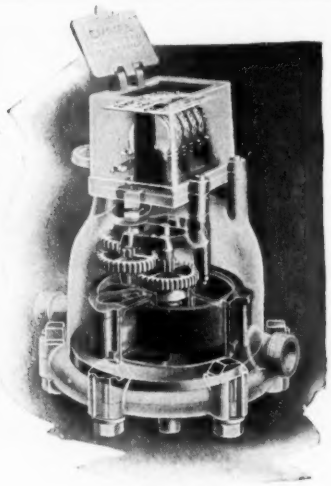
WATER METERS THAT LAST



It is not their successful performance when first installed, but their staying qualities and length of life that make them a truly practical and profitable investment.

Accuracy in water meters is now, as always, the first essential; but it must be an enduring accuracy, uninterrupted by repairs and maintained steadily over long terms of hard service

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can offer just that sort of a record. It has been proved by numerous tests to be the most accurate meter on the market and its lasting qualities are unsurpassed. Many have been in use for over 25 years without the need of a single repair, and are still registering satisfactorily.

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WATER METERS

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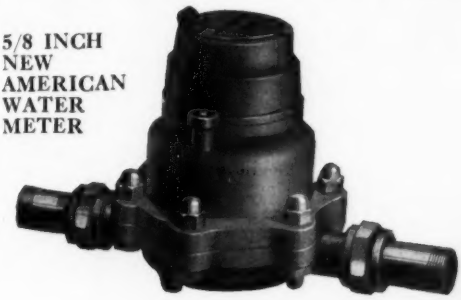
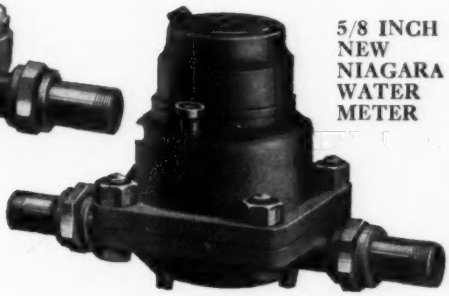
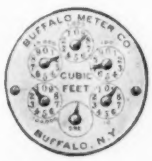


5/8 INCH NEW NIAGARA WATER METER



Niagara and American Meters are of the disc type. The Niagara Meter has a galvanized cast iron outside casing; the American Meter has a bronze main casing with either a bronze base or a galvanized cast iron base. The works in the three different casings are the same and interchangeable. Upon opening the meter at the bolted flange, each intermediate gear may be immediately removed from its bearing, the measuring chamber lifted from its seat, the strainer slipped out, or the register tried by turning the stuffing box gear. All submerged working bearings are protected against sand and sediment. The hard rubber measuring disc is reinforced with a metal plate. Purchaser has option of round reading or straight reading register indicating cubic feet, U. S. gals., imp. gals. or litres.

Round Reading Register



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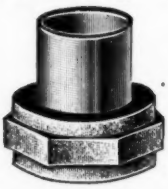

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1920

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J. M. DIVEN, Secretary

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applied with
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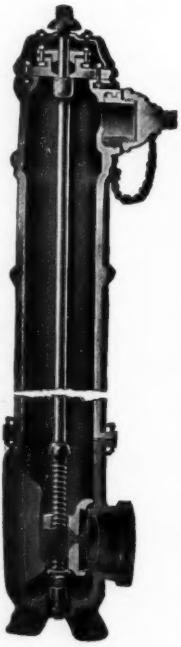

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Efficient **Frost-Proof**

"All parts removable without digging up hydrant. Special device prevents street from being flooded should standpipe be broken. Minimum expense to install and maintain."

Office & Works Troy, N.Y.

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Regulating Valves for High Pressure

The regulation of Reservoirs, Stand Pipes, etc. Steam, Water or Air

Our Regulating Valves control the High Pressure Fire Service Systems of

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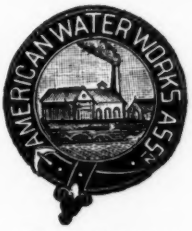
ROSS VALVE MFG. CO. **TROY, N. Y.**



OFFICIAL BADGE

BADGES

THE AMERICAN WATER WORKS ASSOCIATION

The above cut is a facsimile, slightly enlarged, of the official badge or emblem of the Association. It is of gold and blue enamel, made with a pin, but can be made as a button or watch charm

The price in solid gold is $6.00 and they can be procured from the secretary.

A smaller badge of the same design, made as a button, can be made, size about that of the inside circle of the one illustrated above, for about $2.50, if an order for fifty is received. The smaller badge will be an exact counterpart of the large one in every detail. The order for fifty is necessary to secure the new dies for their manufacture.

For badges address

J. M. DIVEN, Secretary
153 W. 71st St., New York, N. Y.

These badges are not to be confused with the usual convention badge, but are for everyday use.

LOCK JOINT WATER PIPE

36 Inch Reinforced Concrete

LOCK JOINT WATER PIPE

Laid through Cumberland Mountains

BUILT FOR PERMANENCE

FEATURING : Low Initial Cost. Smooth Flow Line. Minimum Laying and Operating Costs. Strength. Durability.

EVERY JOINT AN EXPANSION JOINT

Lock Joint Pipe Renders Maximum of Service Water Lines, Storm and Sanitary Sewers, Culverts, Subaqueous Intakes and Outlets

STANDARD CULVERT AND SEWER PIPE
12" to 48" in Stock for Immediate Shipment

LOCK JOINT PIPE CO.

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CLARK

Means standardization, and represents "ABSOLUTE GUARANTEE, a warrant of satisfaction."

Write for catalog 20 illustrating CLARK METER BOXES, Valve Housings, Valve Boxes, Clark Meter Testers, Underground Leak Indicators, etc.

Prompt shipments at all times.

EVERYTHING FOR THE WATER WORKS

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The Clark Valve Housing

HYTEMPITE

(Reg. U. S. Pat. Off.)

A dense, refractory plastic material, scientifically compounded, for bonding fire brick and for kindred uses.

It forms a lasting union between materials joined, sets at normal temperatures and retains its strength up to temperatures at which the best quality of fire brick will become soft.

It can be used as a binder wherever fire-clay brick, silica brick or tile are used.

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Agents in 36 Cities **26 Cortlandt St., New York, N. Y.**

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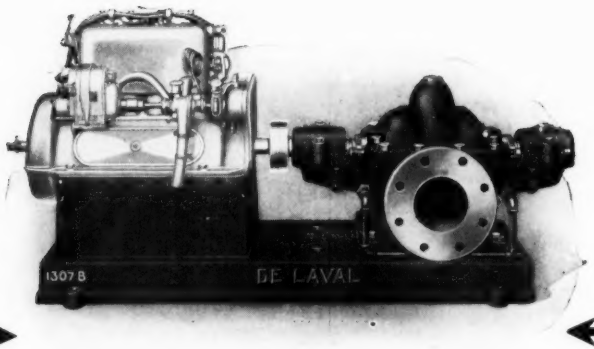
BRASS GOODS

"The kind you wished you had always used"

GUARANTEED FOR FIVE YEARS

GLAUBER BRASS MFG. CO. Cleveland, Ohio



De Laval 6-in. centrifugal pump driven by gas engine
960 gals. per min. against 35 ft. head.

Pumping by Gas Power

THE gas, gasoline or oil engine offers convenient and inexpensive power for pumping. The speeds of gasoline engines harmonize very well with those of centrifugal pumps, and gears are usually unnecessary. There are no pump valves, and only the two simple packings about the shaft. The bearings, the only parts requiring lubrication, are ring-oiled. The few parts subject to wear, such as bearings, shaft sleeves and impellers, can easily be renewed, as De Laval pumps are built upon a limit-gage interchangeable basis. All working and wearing parts are accessible upon lifting the casing cover and bearing caps. The water delivery is smooth and without shock or pulsation, and no injury results should the discharge be suddenly cut off or opened wide.

All De Laval pumps are guaranteed as to capacity and efficiency and are thoroughly tested before leaving the works.

State your pumping requirements in detail, and our engineering department will make recommendations.

Ask for Catalog W-94.

DE LAVAL STEAM TURBINE CO.

Trenton, N. J.

99

THE HILL CUP

THROUGH the generosity of the MINNESOTA SECTION, the Hill Cup, an award given by Mr. Nicholas S. Hill, Jr., for the Section showing the greatest percentage of gain in a year, and to be the permanent property of the Section securing it for three consecutive years, is again in competition this year.

The Minnesota Section secured the cup for three consecutive years, the last being the year when we were at war and the whole Association suffered from war conditions. This Section just to show its "Good Sportmanship" has generously offered to put the cup up again this year, saying they are going to win it anyway, and daring the other Sections to try to get it away from them.

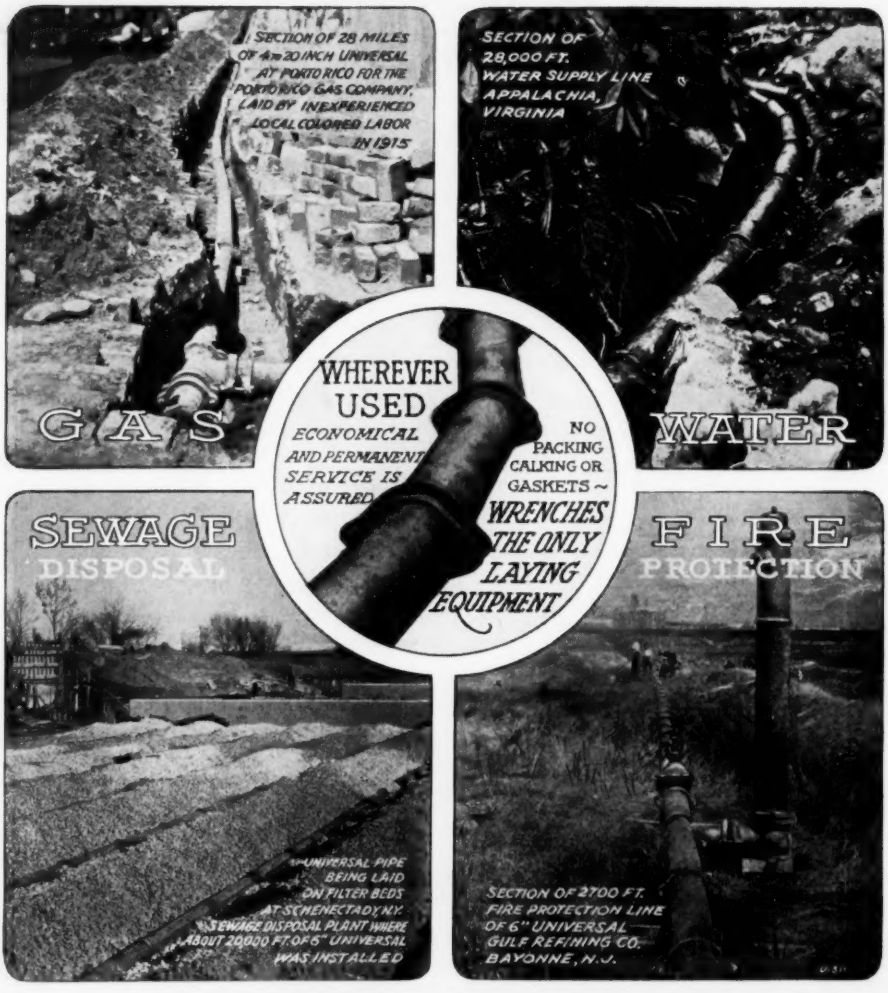
The Secretary of your Section will have charge of the contest. Get your instructions from him.

The contest is a percentage gain, so the little section stands just as good a chance as the big one.

GET BUSY
MAKE YOURS THE BANNER SECTION

CONTEST CLOSES THE FIRST DAY OF THE CONVENTION

UNIVERSAL CAST IRON PIPE


SECTION OF 28 MILES OF 4 to 20 INCH UNIVERSAL AT PORTO RICO FOR THE PORTO RICO GAS COMPANY, LAID BY INEXPERIENCED LOCAL COLORED LABOR IN 1915
GAS
SECTION OF 28,000 FT. WATER SUPPLY LINE APPALACHIA, VIRGINIA
WATER
WHEREVER USED ECONOMICAL AND PERMANENT SERVICE IS ASSURED
NO PACKING CALKING OR GASKETS ~ WRENCHES THE ONLY LAYING EQUIPMENT
SEWAGE DISPOSAL
UNIVERSAL PIPE BEING LAID ON FILTER BEDS AT SCHENECTADY, N.Y. SEWAGE DISPOSAL PLANT WHERE ABOUT 20,000 FT. OF 6" UNIVERSAL WAS INSTALLED
FIRE PROTECTION
SECTION OF 2700 FT. FIRE PROTECTION LINE OF 6" UNIVERSAL GULF REFINING CO. BAYONNE, N.J.

WE WILL GLADLY SEND DETAILED INFORMATION

~ THE CENTRAL FOUNDRY COMPANY ~

90 WEST STREET, NEW YORK

CHICAGO, ATLANTA, DALLAS, SAN FRANCISCO.

DIFCO

ACCURACY is the goal of all work in bacteriology as well as in chemistry. It is better served when all bacteriologists work with uniform culture media, standardized to a high degree of uniformity, as in the use of "Difco" Culture Media, Dehydrated. Uniformity of cultural factors is assured, either for the same worker at different times, or for different workers at the same time.

SPEED is greatly desired in bacteriological procedure and no advance in this respect has been made for many years that compares with the use of "Difco" Culture Media, Dehydrated. The saving in time, as contrasted with the old methods, is easily demonstrated, and the difference is incredible.

CONVENIENCE becomes a prime consideration when accuracy and speed are at stake. The convenience of "Difco" Culture Media, Dehydrated, can be appreciated only by actual trial. Think of having a dozen different formulas in convenient packages on your shelves, needing only one weighing and the addition of water to obtain a medium ready to sterilize.

ECONOMY is a consideration when quality has been satisfied. The use of "Difco" Culture Media, Dehydrated, assures economy, not only thru the factors of Accuracy, Speed, and Convenience, but by actual comparison of costs, based on materials, labor, and time.

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More than a dozen standard formulae, all carried in stock by the principal dealers in scientific supplies. Descriptive Bulletins upon request.

YOUR INQUIRIES ARE SOLICITED

DIGESTIVE FERMENTS COMPANY

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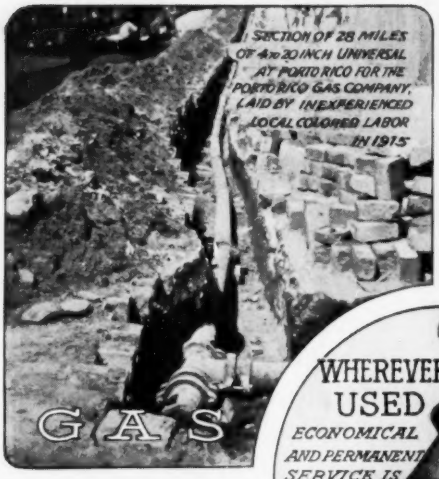
UNIVERSAL CAST IRON PIPE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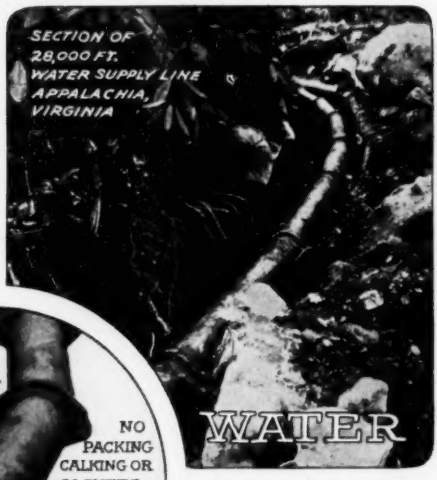

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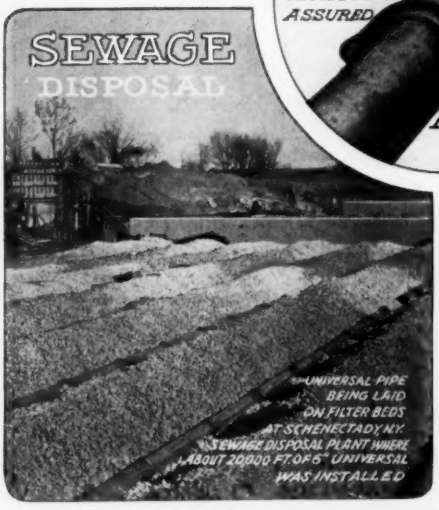
ECONOMICAL AND PERMANENT SERVICE IS ASSURED
NO PACKING CALKING OR GASKETS ~ WRENCHES THE ONLY LAYING EQUIPMENT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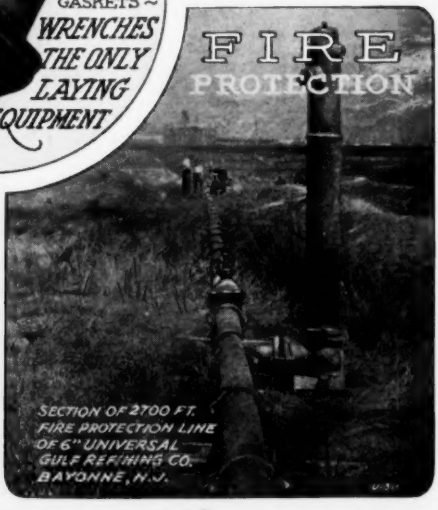

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Sectional Valve Housings

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Proper Protection—Quick Accessibility for Repairs or Operation.

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